Anatomy and Physiology for Radiographers

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Preface to Second Edition

In this edition revision of the text has been carried out, there has been some rearrangement of subject matter and certain sections have been rewritten or expanded. The author is grateful to Dr. Paul Dee for his many valuable suggestions particularly with regard to the chapter on the Endocrine System which Dr. Dee has largely rewritten and to his secretary, Miss Sybil Wiper, for her help. Several new illustrations have been added for many of which the author is indebted to Miss Dorothy Mustart, A.T.D.

The Society of Radiographers has graciously allowed the author to include in Advice to Student Radiographers (p. viii) comments which have been made by the Society's examiners.

It is the earnest hope of the author that this small book will continue to be of use to the student radiographer and other medical auxiliaries.

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Preface to First Edition

This book is intended primarily for candidates studying for Part I of the M.S.R. examination. It meets the requirements of the by syllabus. Material on Radiographic Anatomy and the Biological effects of Radiation has been included to add to the general usefulness and interest of the book and sections on ossification of the various regions are provided for reference although not required by the current syllabus.

The author's thanks are due to his many colleagues who have given permission to reproduce illustrations from the following books: *Anatomy and Physiology for Nurses* by W. G. Sears, *Anatomy for Students and Teachers of Physical Education* by J. W. Perrott, *Anatomy and Physiology for Students of Physiotherapy, Occupational Therapy and Gymnastics by* C. F. V. Smout and R. J. S. McDowall, *Anatomy for Dental Students* by M. L. Keene and J. Whillis, *Practical Anatomy* by Sir Wilfred Le Gros Clark.

The author is indebted to Dr. Arnold Appleby and Mrs. R. I. McCallum for their interest and help in correcting the manuscript.

C. K. WARRICK

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Advice to Student Radiographers

The best way in which to commit to memory the material covered in class is to read the subject up as soon as possible whilst it is still fresh in the student's mind. The student should take every opportunity he can of studying the bones and handling models of anatomical structures.

Some of the questions in Part 1 of the M.S.R. include a supplementary question on pathology which the examiners expect to be answered very simply. The student is advised, in this connection, to study the patient's request card or radiotherapy notes, etc., to ask questions of his seniors and to carry about with him and refer frequently to one of the small books on pathological terms and definitions recommended by the Society.

The examiners repeatedly comment on the phonetic spelling of scientific terms which suggests that there is insufficient use of text-books.

In the examination clear anatomical drawings are required and *not* drawings of radiographic appearances. The student must be very careful to read the question carefully and to avoid irrelevant material in his answer.

In illustrating synovial joints it has been suggested that in their homework and in the Examination candidates should use the colours which standard anatomical works use for the synovial membrane (red), the articular cartilage (yellow) and the capsule (blue). Further, the synovial joint should be described in the order indicated on p. 34.

In describing an organ the candidate should try to do so in the following order:

1. Position
2. Shape
3. Size
4. Leading from . . . to . . .
5. Important relations
6. Structure
7. Blood and nerve supply
8. Lymph drainage

I

General Anatomical Terms

Human anatomy is the naked eye study of the structure of the body; the study of the minute structure of the tissues as revealed by the microscope is called *histology*. **Human physiology** is the study of the functions of the normal body and *pathology* is concerned with diseases and the changes resulting from them.

The body consists of the head, the neck, the trunk and the four limbs. The trunk is divided into the thorax, in which are the heart and lungs, and the abdomen. In the upper part of the latter are the kidneys, the liver, the spleen and most of the digestive system; in the lower part, called the pelvis, are the rectum, the bladder and (in the female) the organs of reproduction.

Each upper limb consists of the arm, the forearm, the hand, the thumb and the four fingers. The thumb is the first digit and the little finger is the fifth. Each lower limb consists of the thigh, the leg, the foot and the toes.

For the purposes of anatomical description it is usual to consider the body as if it were always in a standard position, namely, standing erect facing the observer with the arms hanging by the sides and the palms of the hands facing forwards. With the body in this 'anatomical' position it is possible to define certain terms which are in constant use in anatomical descriptions.

The front of the body is its *anterior surface*, the back is its *posterior surface*, the head is at the *superior or cranial end* and the feet are at the *inferior or caudal (tail) end* of the body. Structures lying nearer the midline are said to be *medial* to those which are *lateral* and lie further from the midline. In the limbs the underlying bones give their names to alternative descriptions for medial and lateral – for example, in the forearm the medial and lateral sides may be called the ulnar and radial respectively and the medial and lateral sides of the leg may also be called the tibial and fibular.

Parts of the limbs which lie nearer the trunk are said to be *proximal* to those which, lying further away, are said to be *distal* or *peripheral*. Thus the knee is distal to the hip and the elbow is proximal to the wrist.

The anterior surface of the hand is called the *palmar surface* and the posterior surface or back of the hand is called the *dorsum.*

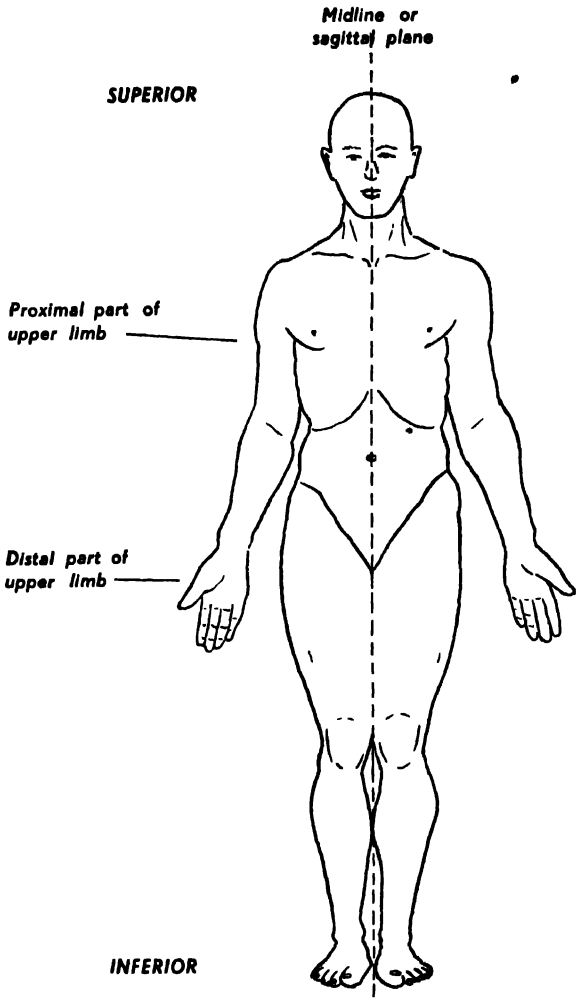


Fig. 1.1 The 'anatomical position'.

The vertical plane which passes through the midline of the body dividing it into right and left halves is the *median* or, as it passes through the sagittal suture of the skull, the *sagittal plane.* The vertical

plane which passes through the coronal suture of the skull at right angles to the sagittal is the *coronal plane*. Planes parallel to these are also called sagittal and coronal respectively. *Transverse* or *horizontal planes* through which cross sections of the body may be made are at right angles to both the vertical planes.

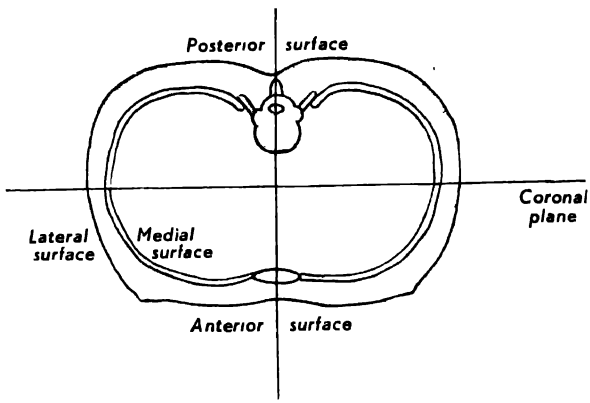


Fig. 1.2 Transverse section through the trunk showing the sagittal and coronal planes.

A subject in the *supine* position is lying on his back. One in the *prone* position is lying face down.

The *posterior* (or anteroposterior or A.P.) radiographic *projection* means that the posterior surface of the patient or limb is nearest the film. The *anterior* (or postero-anterior or P.A.) *projection* is taken in the reverse way with the anterior surface of the patient or limb nearest the radiograph.

2

Cell Structure and Function

The human body is composed of tissues which are made up of *cells* of various kinds (e.g. nerve-cells, muscle-cells, etc.) and the *extracellular* material, most copious in fibrous tissue, cartilage and bone, which the cells produce. Cells are so small that they can only be studied with powerful microscopes but each is a tiny living organism which exhibits many of the properties of the body as a whole.

A cell consists of *protoplasm* which is a colourless jelly-like substance composed of water, mineral salts and complex organic compounds called proteins. By the use of certain staining methods the microscope reveals that the protoplasm of the cell is a delicate reticulum (network) containing within its meshes a more fluid

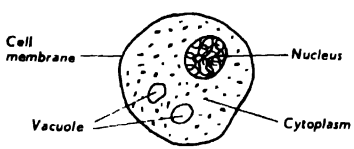


Fig. 2.1 The general structure of a cell.

portion. Most cells are surrounded by a thin membrane which is permeable to certain substances so that nutritious material may enter it and waste products may leave. Near the centre of the cell is a globular structure known as the *nucleus*, the living matter of the cell apart from the nucleus is called the *cytoplasm*.

The nucleus contains a number of small rod-like structures called *chromosomes* upon which the life of the cell depends. Chromosomes are of extremely small size and they can only be studied by powerful microscopes after being specially stained. In human cell nuclei there are forty-six chromosomes grouped into twenty-three pairs; at particular points along them they possess structures termed *genes* which transmit hereditary characteristics.

Scientists and philosophers cannot satisfactorily define life but it is possible to enumerate some of the activities which characterize

living things. All living organisms require to breathe, all must feed, all need to excrete their waste products, all are able to reproduce and all exhibit some degree of irritability and contractility.

These activities must be studied in greater detail.

1. **Respiration.** The energy required for the activities of the body is obtained from the breaking down of food products by oxidation. This process requires oxygen, and carbon dioxide is produced as a waste product; the means by which oxygen is supplied and carbon dioxide is removed is known as respiration.

2. **Digestion.** The energy the body expends and the material required for growth and the replacement of cells and tissues are derived from the food which it is the function of the alimentary canal to take in, digest and absorb. Digestion is the process of converting the food into a form in which it can be absorbed through the intestinal wall to enter the blood stream. It is performed by *enzymes* or ferments which are present in the saliva and in the gastric, intestinal and pancreatic juices.

3. **Metabolism.** A cell obtains from its food both the energy to perform its function and the material from which to make new protoplasm either for growth or for making good the effects of wear and tear. The chemical processes by which food is converted into energy or new protoplasm are called *metabolism.* It is usual to subdivide metabolism into the building up processes – *anabolism,* and the breaking down processes which result in the production of heat or the performance of work which are known as *catabolism.*

4. **Excretion.** The metabolic processes in the cell result in the production of waste products or excreta which consist mainly of

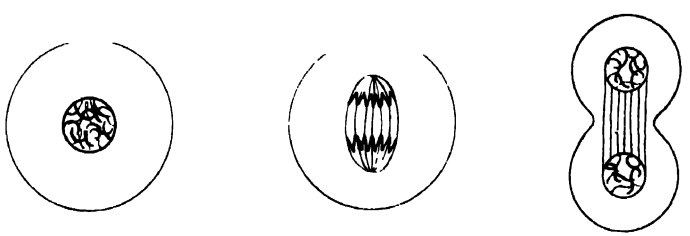


Fig. 2.2 Cell division by mitosis.

A Cell before mitosis showing nucleus. B During mitosis, the nucleus has become spindle-shaped and the chromosomes, shown by denser lines, have split longitudinally and are migrating to its opposite poles. C The nucleus and cell are dividing into two and the two daughter cells being formed will each have a full complement of chromosomes.

nitrogenous matter such as urea and uric acid, water and carbon dioxide. These pass through the cell wall into the tissue fluid which surrounds it and so reach the blood stream. Nitrogenous excreta and water are extracted from the blood by the kidneys, the skin excretes water in the form of sweat and the lungs excrete carbon dioxide and water.

5. **Reproduction.** Cells multiply by dividing into two by a complex process known as *mitosis*. In order that the two daughter cells so formed may each contain its share of chromosomes the individual chromosomes split longitudinally into two during the process of cell division. Thus the total number of chromosomes in the daughter cells is the same as in the parent cells.

6. **Irritability and contractility.** The power of an organism to respond to stimuli and to adapt itself to its surroundings depends on its irritability and contractility. In the higher animals cells vary in their responses to stimuli. A muscle-cell responds by contracting, a gland by secreting, the cells of the retina of the eye respond to the stimulus of light and those of the ear to sound.

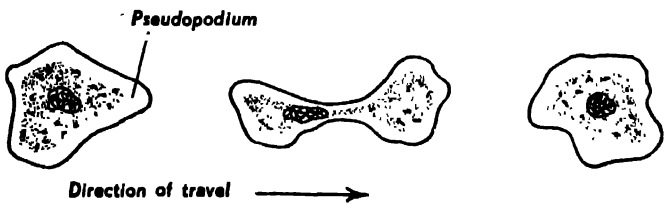


Fig. 2.3 The amoeba. Illustrating the mode of progression known as amoeboid movement.

In the human body some cells, muscle-cells for example, show a high degree of contractility and others, such as the white blood corpuscles, exhibit a type of movement called *amoeboid*. This takes its name from the *amoeba*, a microscopic unicellular organism living in pond water which progresses by throwing out a protoplasmic process or *pseudopodium* ('false foot') in the direction in which it desires to go. The protoplasm is withdrawn from the opposite side of the cell and flows into the pseudopodium which represents the new position of the cell.

The Sex Cells, Fertilization and Early Development

In the human being, as in most animals, a new individual arises as a result of fusion of a single cell derived from the male parent with one derived from the female. These are known as the *spermatozoon* and *ovum* respectively. The fusion of the spermatozoon and

the ovum results in *fertilization* of the latter. The spermatozoon and the ovum have arisen by a special form of cellular reproduction distinct from mitosis termed *meiosis*. The cells resulting from meiotic division only contain half the number of chromosomes typical for the cells of the species so that when the ovum is fertilized the full complement of forty-six chromosomes is restored. The fertilized ovum has thus obtained half its chromosomes from the male parent and half from the female parent. The chromosomes will determine the make-up of the individual, for example, whether he has blue eyes or brown eyes, the shape of the ears, the colour of the skin, etc., and whilst the individual will not be exactly like either parent it is a matter of common observation that the certain physical and mental characteristics of parents seem manifested in their offspring.

The *spermatozoon*, of which many millions are produced at each ejaculation, is a tadpole-like unicellular structure consisting of a head part in which is the nucleus, a middle part and highly active tail. The spermatozoon propels itself by vigorous action of its tail from the vaginal vault where it will have been deposited to the uterine tube where it is capable of surviving for a few days, during which it may meet and fertilize an ovum.

The *ovum* is a large cell which is shed monthly by the ovary at the time of ovulation (p. 226). The ovum is believed to attract spermatozoa by some form of chemical action, a process known as *chemotaxis*. The ovum is carried by ciliary action along the uterine tube where it may encounter spermatozoa. The first spermatozoon to reach the ovum will fuse with it and thus fertilize it.

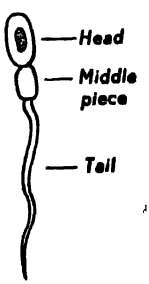


Fig. 2.4 Spermatozoon or male sex cell.

The fertilized ovum, with its full complement of forty-six chromosomes, divides by mitosis into two cells, so that four, eight, sixteen and thirty-two cells, etc., etc., are produced. The mulberry-shaped mass of cells thus formed (the *morula*) buries itself in the wall of the uterus and as division proceeds it becomes hollowed out into a relatively thin-walled, fluid-filled structure, the *blastocyst*. At one pole of the blastocyst is a mass of cells in which two cavities soon form; one is the *amniotic cavity* and the other the *yolk sac*. Intervening between them is the *embryonic plate* where the embryo itself develops; the amniotic cavity enlarges very greatly bathing the embryo in its fluid contents and completely filling the enlarging uterus.

On the exterior of the blastocyst a number of finger-like processes known as *villi* project and anchor it to the uterus; later these take

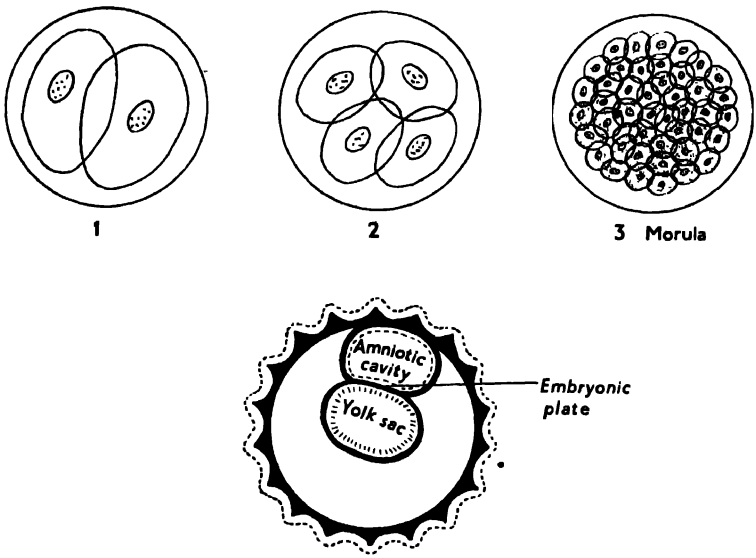


Fig. 2.5 Segmentation of the ovum leading to the formation of the morula (3) and the blastocyst (4).

part in the formation of the *placenta*. The *foetus*, as the human embryo is called after the eighth week, is connected by the *umbilical cord* to the placenta where gaseous and other interchanges take place between the maternal and foetal circulations but no actual mixing of the blood occurs.

The embryonic plate consists of three layers of cells known as the ectoderm, the endoderm and the mesoderm. These are the *three germ layers* from which all the tissues of the body develop. The *ectoderm* gives rise to the skin and the nervous system; the *endoderm* to the epithelial lining of the alimentary, the respiratory and the urinary tracts. The *mesoderm* forms the connective tissues which include the skeletal system and the muscles and it also forms the blood vessels and most of the organs of the body.

By the eighth week the embryo has grown to about 1 inch in length; after this it is known as the foetus and it attains the length of about 8 inches by the sixteenth week. At this time there is usually sufficient calcium in the skeleton for the presence of the foetus to be demonstrated by radiography. The mother becomes aware of foetal movements by the twentieth week and birth occurs at about the fortieth week.

3

The Tissues. The Systems. The Skin. Cartilage and Bone. Some Biological Effects of Radiation

THE TISSUES

Just as a wall may be built of similar bricks so are the tissues formed of collections or aggregations of similar cells. It is usual to recognize four essential tissues:

1. Epithelial tissue.
2. Connective tissue.
3. Muscular tissue.
4. Nervous tissue.

Some of these tissues consist not only of cells but of varying amounts of extracellular material which the cells produce. Fibrous tissue, cartilage and bone have a conspicuous amount of extracellular material in their composition (see below).

1. **Epithelial tissue** is composed of closely packed cells with sparse extracellular material between them and its function varies with its situation so that it may be found acting in a protective, a secretory, an absorptive or an excretory role.

It is usual to classify epithelial tissue into simple, consisting of a single layer of flattened cubical or columnar cells, and compound, which is composed of several or many layers of cells.

Simple epithelium is found lining the glomeruli of the kidneys, the air cells of the lungs and the surfaces of the peritoneum and pleura and forming the walls of capillaries. *Ciliated columnar epithelium* is a variety of simple epithelium composed of columnar cells with fine projections (cilia) from their free surface and it is found in the respiratory tract and the uterine tubes. The movements of the cilia result in the propulsion in one direction of material in contact with the epithelium and it is by this method that material is expelled from the accessory nasal sinuses.

The secretory glands of the body are composed of *cubical* or *columnar* epithelium and their secretions are passed either directly into the blood stream (the ductless glands, Chapter 16) or through a duct (a narrow tubular structure) on to the surface of the skin or mucous membrane. The latter group are called the glands of *external secretion* and the simplest type is shaped like a test-tube whose walls are made up of cubical or columnar cells. The secretions of these cells are passed into the 'tube' and so reach the appropriate surface. The simple tube-like arrangement may be elaborated by elongation and coiling (e.g. sweat glands) or by a multiplicity of simple tubes opening into a common duct (e.g. salivary glands).

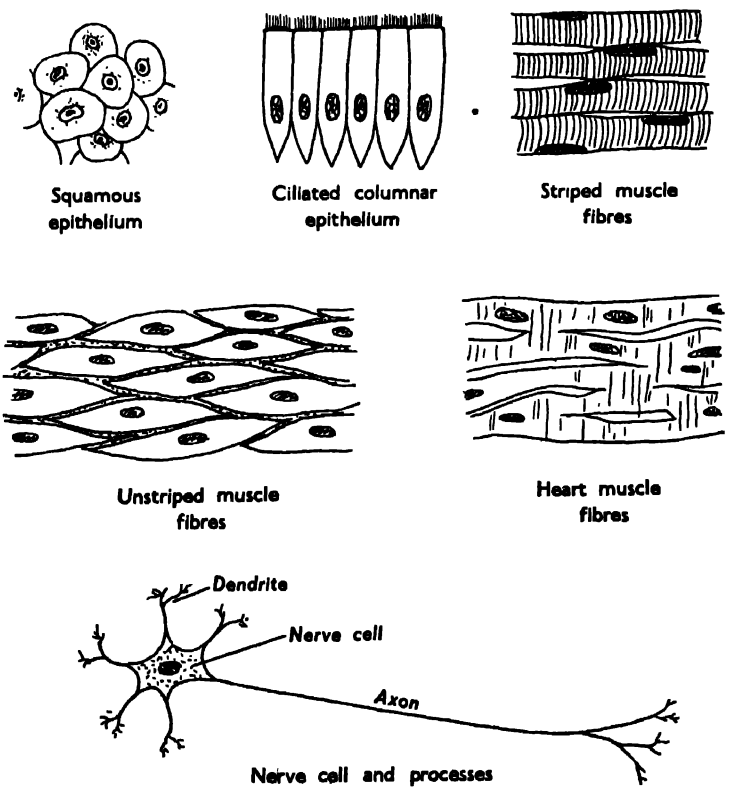


Fig. 3.1 Some of the different kinds of cells found in human tissues.

Compound epithelium is found commonly in two forms: the *stratified squamous epithelium* which makes up the epidermis of the skin and the mucous membrane lining the mouth, pharynx and oesophagus, and the *transitional epithelium* found in the bladder and ureters.

2. **Connective tissue** is the most widely spread of all human tissues and its function is to provide a supporting framework for individual organs and for the body as a whole. Connective tissue is characterized by the abundance of extracellular material and the relative sparsity of its cells. *White fibrous tissue* is made up of bundles of fibres and is the chief component of tendons and ligaments. *Elastic tissue* contains elastic fibres in addition to white fibrous tissue and is found in the arteries, bronchioles and vocal cords. *Areolar tissue*, often described as packing tissue, is found in the subcutaneous tissues, beneath mucosal surfaces and surrounding the blood vessels. It consists of a combination of fibrous tissue, elastic tissue and gelatinous material. *Fatty tissue* is composed of cells which contain globules of fat. *Blood* and *lymph* are tissues in which the extracellular material is completely fluid and the cells are carried round the body

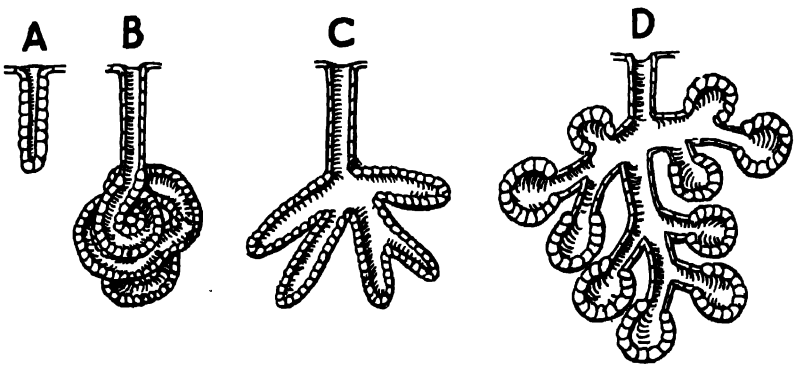


Fig. 3.2 Types of glands:
A Simple tubular; B Coiled tubular;
C Branched tubular; D Racemose.

in the moving stream. In *cartilage* and *bone* the extracellular substance is solidified and in bone mineral salts are deposited in it.

3. **Muscular tissue** is composed of bundles of fibres and three types are usually recognized. *Striped* or *voluntary muscle* takes its name from the fact that its fibres show transverse stripes when it is examined with the microscope. *Unstriped or involuntary muscle* is found in organs not under voluntary control such as the intestines, urinary tract and uterus and its fibres do not show transverse stripes. *Heart muscle* is grouped separately although it is involuntary muscle, for the fibres, although different from voluntary muscle, do show transverse stripes.

4. **Nervous tissue** is composed of nerve-cells, nerve-fibres and a special type of connective tissue called *neuroglia*. The nerve-cells are

found in ganglia and in the grey matter of the central nervous system; they receive and store impressions and initiate outgoing impulses which are conducted to and from the cell at varying speeds along the fibres. A nerve-cell and its fibres constitute a *neuron* and usually only one process, the *axon*, conducts impulses from the cell but often several, called *dendrons*, conduct impulses towards the cell. Nerve-cells, like muscle-cells, are incapable of reproduction and therefore after destruction they cannot be replaced.

Membranes

Thin layers of tissue which line body cavities are called membranes. The most important of these are (1) mucous, (2) serous, (3) synovial.

(1) *Mucous membranes* line the nose, the mouth, the respiratory and the alimentary systems, the bladder, the ureters and the urethra, etc. They are composed of simple and compound epithelia of which the cells may be squamous, columnar, ciliated, etc., and some of the cells produce mucus which has a lubricating and protective function.

(2) *Serous membranes* are those which line the large body cavities, namely, the pleura, the pericardium and the peritoneum. They are composed of a single layer of squamous epithelium with a connective tissue base. The surfaces are kept slightly moist and enable the structures which they cover to glide over each other with a minimum of friction.

(3) *Synovial membranes* are structurally similar to the serous membranes and line the capsules of joints and the sheaths of tendons. They are slightly moist and enable movements of joints and tendons to occur without friction.

THE SYSTEMS

The various tissues in different combinations form the organs and structures of the body which can be grouped into a number of systems.

1. The *locomotor system*: the bony and cartilaginous skeleton, the joints and muscles.
2. The *circulatory system*: the heart and the blood vessels.
3. The *respiratory system*: the larynx, the trachea, the bronchi and the lungs.

4. The *digestive* or *alimentary system*: the alimentary canal and associated structures such as the salivary glands, the liver, the biliary apparatus and the pancreas.

5. The *urogenital system*: the organs of urinary excretion and those of reproduction.

6. The *endocrine system*: the ductless glands.

7. The *lymphatic system*: the lymph vessels and nodes.

8. The *nervous system*, the brain, the spinal cord and nerves.

9. The *reticulo-endothelial* system.

It is now proposed to study in more detail the skin, cartilage and bone. The blood will be considered with the Circulatory System (Chapter 10).

THE SKIN

The skin covers the surface of the body and is continuous with the mucous membranes at the various orifices. It consists of two layers; the more superficial, the *epidermis*, is composed of stratified squamous epithelium and is devoid of blood vessels. The deeper layer is the *dermis* or true skin and consists of vascular connective tissue in which cells are relatively scanty.

The *epidermis* is made up of a *horny zone* and a *germinal zone.*

The *horny zone* is composed of three different layers.

(1) The *horny layer* (or stratum corneum) is the most superficial and consists of dead cells whose protoplasm has been converted into a horny substance called *keratin.* This layer is thickest on the palms of the hands and the soles of the feet.

(2) The *clear layer* (or stratum lucidum) also consists of dead cells which have completely lost their nuclei.

(3) The *granular layer* (or stratum granulosum) is the deepest layer of the horny zone; the cells of which it is composed are degenerating, their cytoplasm has become granular but their nuclei are still visible.

The *germinal zone* is composed of two layers.

(1) The *prickle cell layer* lies immediately deep to the granular layer and is composed of sheets of cells which have thorn-like projections, hence the name prickle cell. These cells are alive but they do not usually reproduce.

(2) The *basal layer* is the deepest layer of the epidermis and it consists of a layer of columnar cells. This single layer of cells is the only epidermal layer whose cells reproduce in healthy skin. All the

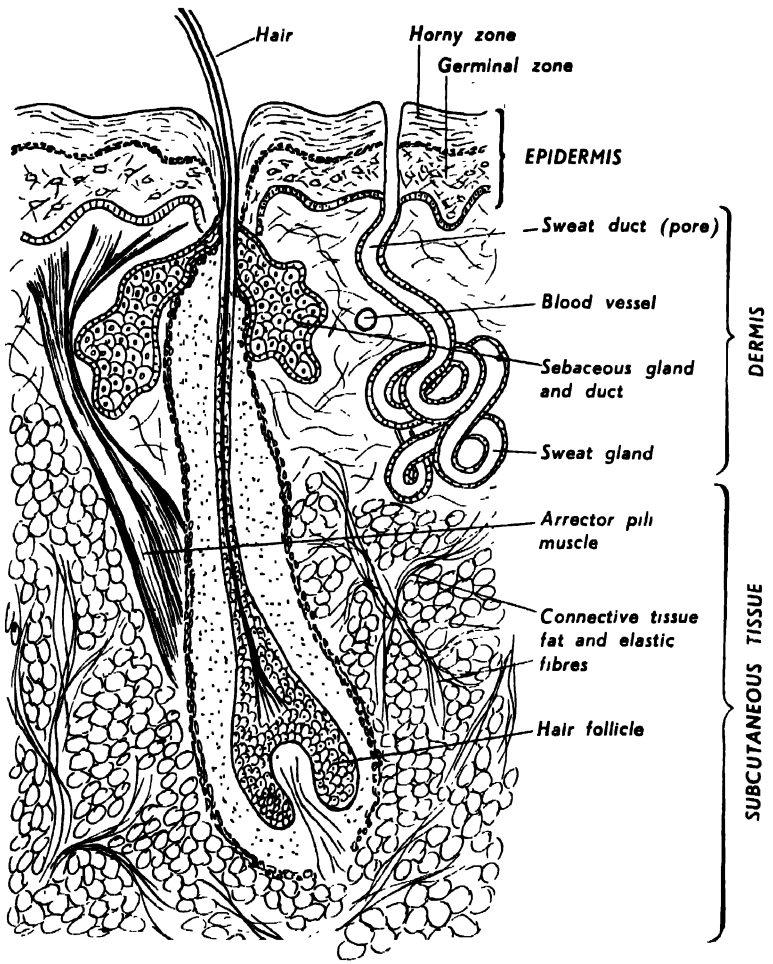


Fig. 3.3 Vertical section of skin.

cells the basal layer gives rise to are gradually displaced superficially and as they move towards the surface they progressively degenerate passing from one layer to the next until they are ultimately shed. The pigment which is responsible for freckles, sun-tan and the colour of the skin in dark-skinned races is situated in the basal and in the deepest parts of the prickle cell layers.

The *dermis* varies considerably in thickness; it is thickest on the palms of the hands and soles of the feet and thin in the skin of the male genitalia and eyelids. Two layers are recognizable in the dermis:

(1) The *papillary layer* consists of numerous highly sensitive microscopic conical projections called *papillae* which are in direct contact superficially with the basal layer of the epidermis. The distribution of these papillae is responsible for the lines and ridges of the epidermis, which differ from one individual to another and form the basis for the study of finger prints in criminology.

(2) The *reticular layer* is made up of interlacing bands of fibrous

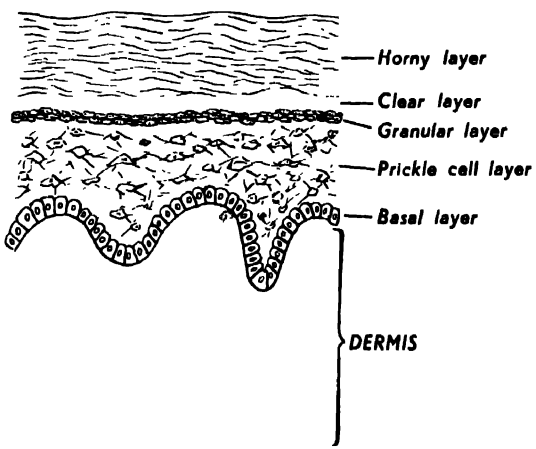


Fig. 3.4 Diagram showing the layers of the epidermis.

tissue and lies deep to the papillary layer. In this layer are found the hair follicles, sweat glands, tactile corpuscles (for sensation, see page 263) and sebaceous glands (grease secreting). Below the reticular layer is the subcutaneous tissue which usually contains fat and separates the skin from the deep fascia and muscles.

The *appendages of the skin* are the nails, the hairs, the sweat glands and the sebaceous glands.

The nails arise from the epidermis and are principally composed of a greatly thickened clear cell layer. Hairs lie in *follicles* which dip deeply into the dermis. The *sebaceous glands* open into the follicles and secrete a greasy substance *sebum*. The *sweat glands* each consist of a long tube which is coiled in its deeper part.

THE FUNCTIONS OF THE SKIN

The skin forms a waterproof *covering* for the body protecting it from mechanical, chemical, bacterial action, etc., and it possesses great powers of regeneration which are, of course, constantly called upon to make good the effects of wear and tear upon it. It gives origin to the hair and nails and is modified in particular parts being very thin over the eyelids and very thick on the palms of the hands and soles of the feet. It has considerable inherent elasticity.

It is an important *sense organ* providing information about the environment particularly with regard to cold, heat, pain and touch which have special end-organs.

It has the ability to *secrete* sweat and sebum and as some of the constituents of sweat are waste products it acts as an *excretory* organ. Sweat consists of water, a small proportion of sodium chloride and traces of excreta.

The principal reason for the secretion of sweat is concerned with the function of the skin to assist in the regulation of body temperature. Body heat is produced by metabolic processes and muscular activity and most of the heat of the body is lost through the skin. The heat regulating centre of the brain controls heat-loss by altering the calibre of the arterioles of the dermis and so varying the blood flow through the skin. The alteration in calibre of the arterioles is effected through their autonomic nerve supply so that stimulation of the sympathetic nervous system causes constriction of the cutaneous arterioles whereas parasympathetic stimulation causes dilation of cutaneous arterioles and increased heat-loss.

Another function of the skin is the *synthesis of vitamin D*. This occurs under the influence of sunlight and constitutes an alternative source of this vitamin which is also present in the food and plays a very important part in the growth of bone (see p. 22). This function of the skin explains why rickets was formerly so common in children living in dark and overcrowded slums, deprived of sunlight and subsisting on a diet deficient in those foods which are richest in vitamin D, namely, butter, milk, cod-liver oil, etc.

CARTILAGE AND BONE

Cartilage and bone are connective tissues consisting of a large proportion of resilient extracellular material which, in the case of bone, becomes impregnated with mineral salts. Most of the bones of the body are first formed in cartilage which is converted into bone by a process known as *ossification*.

Cartilage is a gristly substance in which cells lie in small groups and it is devoid of blood supply. There are three chief types of cartilage:

1. *Hyaline cartilage.* This is a smooth almost transparent material usually found covering the ends of the long bones where it is known as articular cartilage; it is also found in the nose, larynx, trachea and bronchi.

2. *Fibrocartilage.* This consists of cartilage strengthened by bundles of white fibrous tissue. It is found in the spinal intervertebral discs and in the semilunar cartilages within the knee.

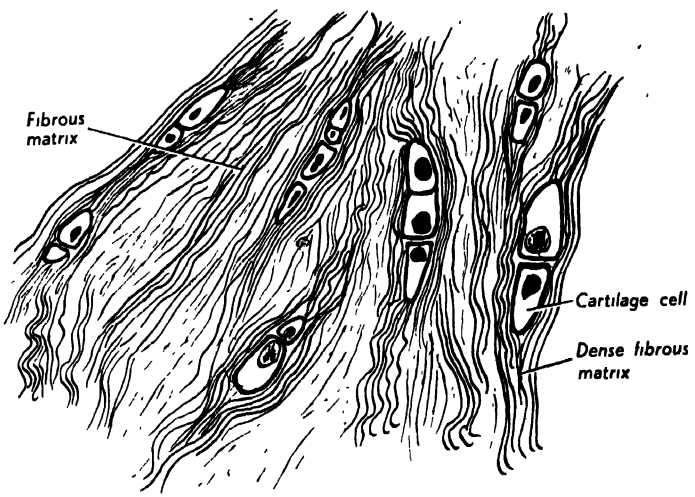


Fig. 3.5 Fibrocartilage.

3. *Elastic cartilage.* This is a combination of cartilage and elastic tissue and is found in such structures as the external ear (pinna) and the epiglottis.

Cartilage often becomes impregnated with calcium salts which render it opaque to X-rays. Thus the costal cartilages and the cartilages of the larynx are often demonstrable in radiographs. This calcification is not a disease process nor is it to be confused with the conversion of cartilage into bone (ossification) which is a much more complex process.

Bone is an extremely hard but slightly elastic variety of connective tissue which is made up of organic and inorganic components. The former consist of cells called *osteoblasts* and bundles of fibres lying

in a ground substance or matrix. The inorganic component consists of calcium phosphate and carbonate and other mineral salts which are laid down in the matrix. This dual composition of bone is of great importance. The organic material may be removed from a bone by burning it, leaving a brittle light structure consisting only of mineral matter. The inorganic or mineral part may be removed by soaking the bone in acid so that it becomes decalcified. Such a decalcified bone consists only of organic matter which is flexible and rubbery and a bone like a rib may be tied into a knot after it has been decalcified.

STRUCTURE OF BONE

If a bone is cut transversely it will be seen that there is an outer layer of *compact bone* of dense ivory-like consistency, an inner layer of *cancellous* or *spongy bone* and a central *medullary* or *marrow cavity*.

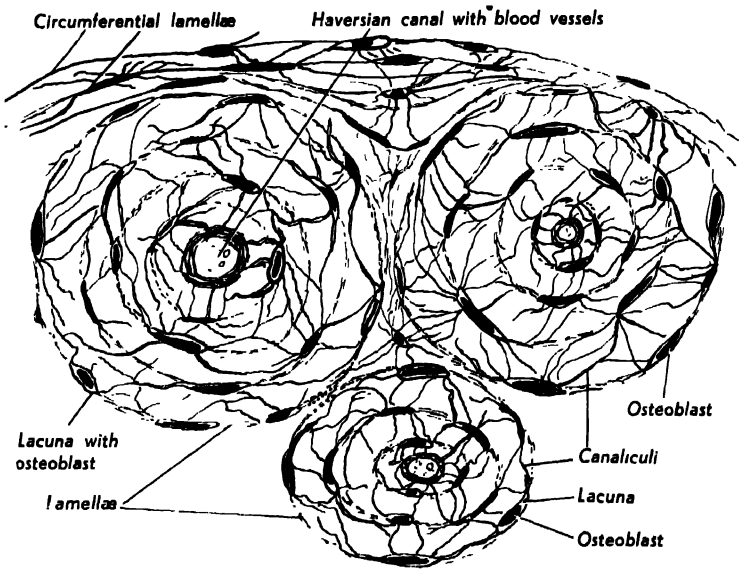


Fig. 3.6 Transverse section of compact bone showing Haversian systems.

Compact bone is seen under the microscope to consist of many similar units called *Haversian systems*. These have a central Haversian canal containing blood vessels, nerves and lymphatics and around the canal are concentric layers of bone running longitudinally called *lamellae*. In the lamellae are small cavities, the lacunae, where the bone-cells (*osteoblasts*) live and these are connected by fine canals (*canaliculi*) which cross the lamellae.

Cancellous or spongy bone is microscopically similar but consists of a network of lamellae in the interstices of which is the *bone marrow*. The marrow fills the medullary cavities and is of two types, red and yellow. Red marrow is the source of most of the blood cells (see p. 167) and in infancy this variety predominates. Yellow marrow is fatty tissue and in adult life it replaces red marrow in the long bones since, after childhood and adolescence are past, blood cells, in healthy individuals, are formed in the flat bones only.

Surrounding the compact bone is the *periosteum* which has an inner osteogenic or bone-forming layer and an outer fibrous layer. The

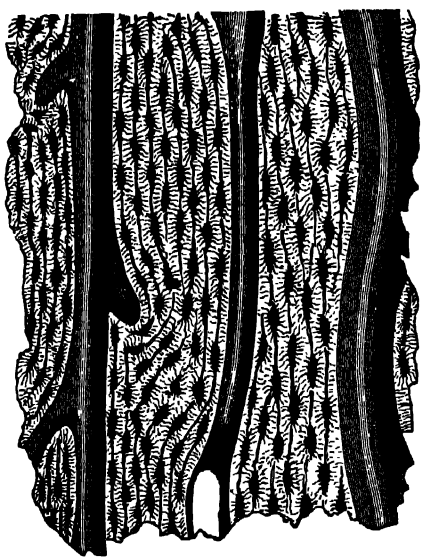


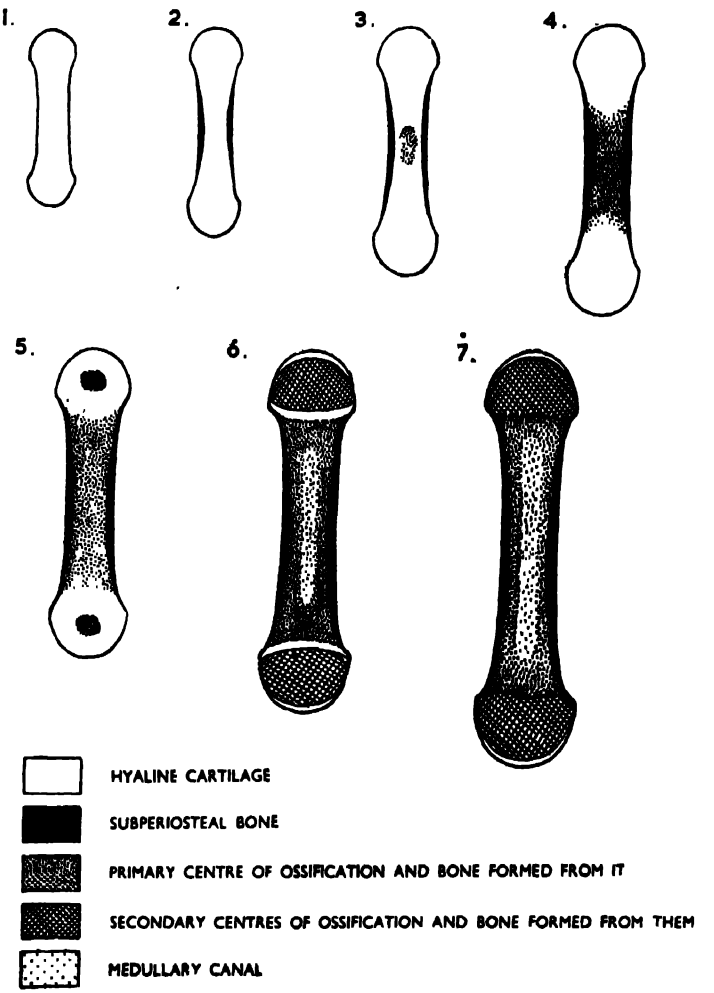
Fig. 3.7 Longitudinal section from the human ulna, showing Haversian canals, lacunae and canaliculi (Rollet).

periosteum is a vascular structure and sends vessels into the underlying cortex. In addition to the periosteal vessels the long bones receive blood from a *nutrient artery* which enters through a short canal often visible in radiographs. The ends of the long bones also receive vessels from those which run in the capsules of the joints of which they form part.

DEVELOPMENT AND GROWTH OF BONE

Most bones develop from rods or masses of cartilage but some, such as those of the skull, are preceded not by cartilage but by

membrane. Thus ossification may be described as being intracartilaginous and intramembranous. There is no essential difference in the process of ossification occurring in these two ways and only the former will be described in greater detail.



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Fig. 3.8 Ossification in cartilage

Intracartilaginous ossification. In the early weeks of intrauterine life buds are formed on the embryo at the sites of the future limbs. Within these limb-buds rods of cartilage develop and by the sixth

week of foetal life a complete cartilaginous model of the skeleton has been formed. The cartilage has next to be converted into bone. This is a gradual process starting, in the case of a future long bone, with the appearance of a *primary centre of ossification* in the middle of the shaft or *diaphysis*. Here calcium is laid down, cartilage-cells die and bone-cells (*osteoblasts*) appear. By the activities of these osteoblasts and the canalizing of the newly formed bone by *osteoclasts* (bone destroyers) the characteristic structure of bone is produced. This process spreads outwards from the primary centre and ultimately involves the whole shaft.

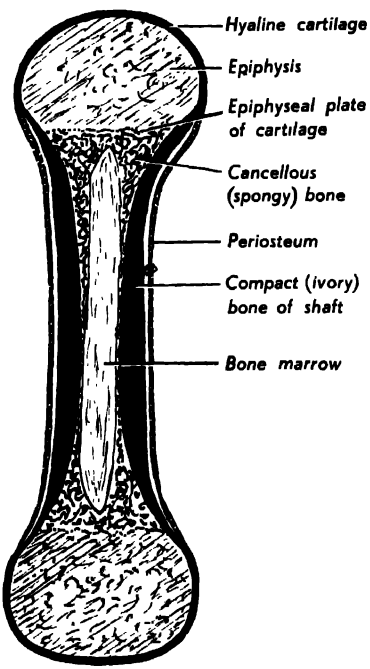


Fig. 3.9 Longitudinal section through the shaft and epiphysis of a long bone.

Secondary centres of ossification appear in the ends of the bones or *epiphyses* (sing. epiphysis) and until growth in length is complete a cartilaginous epiphyseal plate separates the epiphysis from the diaphysis. A radiograph during childhood shows this plate as an apparent gap, the 'epiphyseal line' between the shaft and the epiphysis.

Growth in length of the bone occurs during childhood by the production of bone at the epiphyseal plate in the area known as the *metaphysis* which is simply the end of the shaft adjacent to the epiphysis. Growth in length of a long bone occurs more at one end than at the other. Thus in the lower limb most growth occurs in the region of the knee, so that the lower ends of the femora and the upper ends of the tibiae and fibulae grow more rapidly than the hip and ankle regions. In the upper limb bone growth is less at the elbow than at the shoulder and wrist.

Simultaneously with growth in length there is also growth in circumference resulting from the laying down of bone by the osteogenic layer of the periosteum. In this connection it is of interest to note that if a bone is shelled out from its periosteum (subperiosteal resection) a new shaft may be formed by the osteogenic layer of the periosteum.

As a bone grows in length the ends are carried further apart and since the form of the bone is maintained a certain amount of *remodelling* occurs. This is carried out by osteoclasts.

FACTORS CONTROLLING BONE GROWTH

In life bone is constantly being laid down and it is being constantly destroyed. These processes occur simultaneously and their balance depends on various factors which, if disturbed, may profoundly affect the appearance and strength of the bone.

For normal bone growth to occur there must be an adequate intake of mineral salts, especially calcium and phosphorous, in the diet. Vitamin D is necessary for the absorption of calcium from the bowel and a deficiency of this vitamin results in a disturbance of ossification known as rickets. Certain ductless glands influence bone metabolism and in this connection the parathyroid glands are the most important for they regulate the level of the calcium in the blood and the quantity in the skeleton. Other ductless glands such as the thyroid and pituitary also exert profound influences upon bone.

Bone requires the stimulus of normal activity to maintain its strength and all diagnostic radiographers will be aware that if a limb is encased in plaster of Paris for some weeks it becomes much less radio-opaque – a condition known as disuse osteoporosis. Another factor of importance in the normal development of a bone is the absence of injury to the epiphyseal line and to the epiphysis.

SOME BIOLOGICAL EFFECTS OF RADIATION

X-rays and the gamma rays of radium are called *ionizing radiations* because they are able to displace electrons from the atoms of the matter through which they pass. These ionizing radiations are injurious to cell structure but the exact way in which they effect this injury is not known. The cell nucleus is more susceptible than the cytoplasm and it is especially vulnerable just before the start of mitosis. The chromosomes and the genes which they bear may be injured; the proteins of the cytoplasm and the enzymes which effect various chemical processes within the cell may also suffer. Most tissues of the body can withstand the action of ionizing radiations to some extent and a *threshold dose* probably exists below which no harmful effects may be demonstrated. There may be no threshold dose for the gonads (testes and ovaries) so that even small doses of radiation may temporarily impair the production of normal spermatozoa and ova. For this reason and so as to avoid unnecessary radiation damage to the hereditary mechanism of the sex cells, the genes and chromosomes, it is desirable to exclude the gonads from the primary X-ray beam or to shield them with lead during diagnostic examinations.

In radiotherapy large doses are often given and damage to normal tissues is unavoidable but by skilful planning of the treatment it is usually possible to avoid such a degree of damage that permanent effects of a harmful nature will follow.

The most radiosensitive tissues of the body are lymphoid tissue, bone marrow, the germinal epithelium of the testes and ovaries, the ductless glands and the salivary glands. Less sensitive are the skin and mucous membranes, and least sensitive are bone, muscle and nerve tissue. The cells of malignant tumours are usually more sensitive than normal tissues.

It is not easy to grasp the meaning of the word dose as applied to ionizing radiations for the effects of radiation on the body depend on how big an area of the body is irradiated. Thus if a dose of 500 roentgen units were delivered to a small skin area there might be a reddening with some loss of hair but no general constitutional disturbance, yet if the same dose were given to the whole body 50 per cent of the people so irradiated would die. The greater susceptibility of the body to irradiation of large surface areas is mainly due to the effects of radiation on the bone marrow with consequent depression of the production of blood corpuscles.

The constitutional disturbance which follows the administration

of moderately large doses of radiotherapy to portions of the body and which in its more severe forms is met with in survivors of atomic explosions, where bigger doses of whole body radiation are involved, is called *radiation sickness.*

EFFECTS OF RADIATION ON THE SKIN

The effects of ionizing radiations on the skin are comparable with the effects of other rays which inflict burns such as light and heat. In the past the effect of radiation on the skin was used as a measure of the amount given – the so-called erythema dose. The changes produced in the skin depend on whether the radiation is given in a few relatively large doses (acute irradiation) or in very small doses repeatedly over a prolonged period (chronic irradiation).

Depending on the dosage the acute effects may resolve completely or be followed by certain sequelae. A dose of X-rays of from 300 to 400 r units, i.e. smaller than that required to produce permanent damage, may cause an initial reddening followed by a definite reddening or erythema in 7 to 10 days. This erythema is often accompanied by loss of hair but complete recovery may follow. With larger doses of the order of 1000 to 1500 r units a more severe erythema is produced which may be accompanied by blistering and still larger doses may cause ulceration.

The changes due to chronic irradiation may also be met with as late sequelae to acute irradiation. They may be partly atrophic (wasting away) and partly hypertrophic (due to overgrowth). The skin may become dry, shiny and scaly with sparse and ill-formed hairs, brittle nails and tiny dilated blood vessels known as telangiectasis. There is marked susceptibility to injury and ulcers may form which are resistant to healing; sometimes malignant disease may supervene. The affected area may also show warty outgrowths and these, too, may undergo malignant change.

Since the effects of chronic irradiation may not become apparent for many years radiographers must punctiliously obey the safety precautions laid down in their departments and in documents such as the Code of Practice issued by the Ministry of Health. *They should never, under any circumstances, expose their unprotected hands to the X-ray beam.* By the time changes become apparent the succession of events will be irreversible and irrevocable and the only hope of averting the consequences may be by plastic surgery.

4

Bacteria. Inflammation. Infection. Antisepsis. Ulceration. Neoplasms.

Bacteria

Bacteria are microscopic unicellular organisms which multiply very rapidly; they are widely distributed in nature and are constantly present in the air, water, soil, foodstuffs, etc. Many normally play important and essential roles in natural processes, e.g. the nitrogen-fixing bacteria in the leguminous plants and the cellulose-splitting bacteria which inhabit the large intestines of herbivorous animals. Only a small proportion are pathogenic, i.e. capable of causing disease.

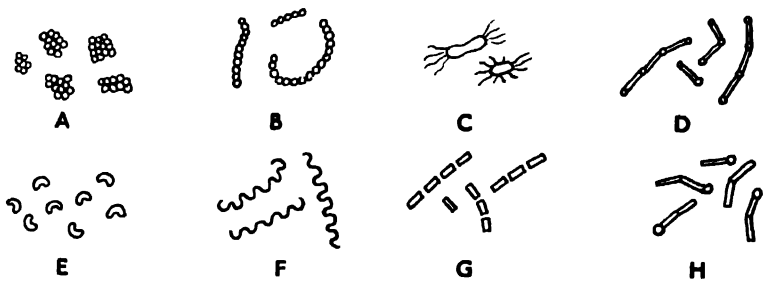


Fig. 4.1 Some Bacteria. A Staphylococci; B Streptococci; C Flagellate bacilli; D Spore-bearing bacilli; E Vibrios; F Spirochaetes; G Non-flagellate bacilli; H Spore-bearing bacilli.

As well as bacteria there are viruses, which are so small that they can only be seen by the electron microscope which is many thousands of times more powerful than the ordinary light microscope. Some bacteria can increase their resistance to the defences of the body by spore formation; a notable example of this is the tetanus (lock-jaw) bacillus which produces highly resistant spores and prolonged sterilization of catgut, dressings, etc., is required to destroy them.

A simple classification of bacteria is based on their shape.

1. *Cocci* are spherical, measure 1/33,000 of an inch (about 1 μ) or less in diameter and are named according to their method of division. Thus staphylococci form clumps and streptococci form chains.

2. *Bacilli* are straight or slightly curved rods and some are mobile because they possess protoplasmic processes called flagella.

3. *Vibrios* are comma-shaped organisms and are usually actively motile, e.g. the cholera organism.

4. *Spirochaetes* are spiral organisms and are longer than other bacteria. Syphilis and a number of tropical diseases are caused by this type of organism.

Pathogenic bacteria and viruses, many of which produce powerful poisons or toxins, and parasites (e.g. malaria) and moulds (e.g. ringworm) are constantly assailing the body which defends itself by (*a*) the general or non-specific defences and (*b*) the specific defences.

(*a*). *The general defences of the body.* The body defends itself against invading organisms in many ways. These include the possession of an intact skin and mucous membranes, certain secretions which are capable of destroying bacteria such as tears, mucus and, especially, gastric acid. The ciliated epithelium which lines the nasal passages, trachea and bronchi can eject particulate matter. When organisms penetrate these barriers they excite an inflammatory reaction by the body (see below).

(*b*). *The specific defences of the body.* These are concerned with counteracting the toxins liberated by bacteria and they may be augmented by artificial means. The introduction of bacteria and their toxins into the body causes it to produce *antibodies*. The antibodies combine with the bacteria and bacterial toxins and tend to neutralize any effects the latter might have on the body. Antibodies which neutralize toxins are often termed antitoxins. The production of antibodies confers a variable amount of immunity, for example, it is very rare to suffer from more than one attack of measles because the first attack produces almost complete immunity. On the other hand influenza is followed by a period of only partial immunity lasting weeks or a few months.

Immunity to certain infections can be produced artificially by *vaccination* in which the patient's own powers of defence are mobilized by injecting preparations of dead bacteria or weak strains of the organism against which protection is desired. Short-term immunization can be produced by the administration of antitoxic serum, e.g. tetanus antitoxic serum is often given to accident cases to protect them from tetanus (lock-jaw). Antitoxic serum is prepared from the

blood of an animal which has survived the disease and it provides the recipient with ready-made antibodies.

INFLAMMATION

This is the reaction of the body to irritation by bacterial infection and physical and chemical injuries. The classical signs of inflammation are heat, redness, swelling, pain and loss of function. These signs are the result of an increased blood supply to the area and transudation of fluid through the vessel walls. An important part of the inflammatory reaction is the passage of white blood corpuscles through the capillary walls into the tissues, where they collect round the injured area and are most numerous in cases of bacterial infection. The white blood cells are phagocytic, which means that they are capable of ingesting foreign matter, dead tissue and bacteria. In most bacterial infections examination of the blood will disclose an increase in the white blood count, this indicates a favourable response by the body. Failure to respond in this way may be a very serious omen. Under favourable circumstances inflammation may be followed by resolution and repair.

INFECTION

If the inflammatory reaction which is excited by bacterial invasion of the tissues is studied under the microscope an intense battle between the bacteria and the white blood corpuscles will be observed. The latter will destroy the bacteria by phagocytosis and in the process many white blood corpuscles will be killed. Unless resolution and repair follow, the local death of tissue and the accumulation of dead leucocytes and dead bacteria will result in the formation of *pus*. If the infection remains localized an abscess may form and by rupturing through the skin it may produce an ulcer (see below).

In addition to the local signs of inflammation which may be present in cases of bacterial infection, varying constitutional symptoms will be caused by toxaemia. Some infections may give rise to an acute illness (i.e. one of short duration) like pneumonia, influenza or boils; others cause chronic (i.e. long continued) illness. Amongst the latter are such conditions as tuberculosis, syphilis and actinomycosis.

ANTISEPSIS AND ASEPSIS

As a result of the work of Louis Pasteur it was established that

bacteria are the cause of wound infection and Lord Lister introduced the antiseptic method of surgery, in which stress was laid not on excluding bacteria from the wound but on killing any which were present. Thus the vicinity of the wound was sprayed with carbolic and the instruments and towels were soaked in this substance. Chemicals which inhibit the growth of organisms are likely to damage the tissues, the patient and others in the neighbourhood and so the antiseptic method was replaced by the aseptic. In this method all organisms are excluded as far as possible from the operation area by strict cleanliness, the use of sterilized (germ free) instruments, the thorough cleansing of the patient's skin and the use of rubber gloves, etc., by the surgeon.

Sterilization is usually performed by exposure to heat or by immersion in antiseptics. Exposure to heat takes various forms. Most bacteria are destroyed by boiling for five minutes but this is not long enough for sterilization of instruments, etc., since boiling for twenty minutes is required to destroy the spores of certain organisms. Steam under pressure in an appliance called an autoclave is widely used and exposure for 15 minutes to a pressure of 15 lb. per square inch above atmospheric pressure raises the boiling point of water to 120° C. and satisfactorily destroys all organisms and spores. Material which cannot be subjected to heat may be sterilized by immersion in antiseptics which are washed off with sterile water before use.

ULCERATION

An ulcer is an unhealed area where destruction of the skin or mucous membrane has occurred. There are many causes of ulceration and amongst these are burns, overexposure to X-rays and radium, acute infections of the skin, vascular disorders, deficient innervation due to spinal or peripheral nerve disease, certain specific infections such as tuberculosis and syphilis and new growths (neoplasms).

NEOPLASMS

Neoplasms, new growths or tumours are abnormal masses of tissue whose growth is unco-ordinated with that of the normal tissues. They are of two kinds, the innocent and the malignant.

The *innocent tumours* usually cease to grow after attaining a certain size. They push structures aside without invading them and they do not cause the death of the individual unless they interfere with some

vital organ. They can usually be removed surgically with complete and permanent cure. Examples are papillomas which grow from epithelium, lipomas from fat, chondromas from cartilage and osteomas from bone.

The *malignant tumours* if untreated will spread remorselessly, sap the patient's strength and ultimately kill him. Malignant tumours show none of the tendency to spontaneous cessation of growth which is a feature of innocent tumours and microscopically they are characterized by the high proportion of cells undergoing mitotic division. Malignant epithelial tumours are called carcinomas and examples are squamous cell carcinoma of the skin and adenocarcinomas of various glandular structures. Malignant tumours of connective tissue are sarcomas; those which arise from fibrous tissue are called fibrosarcomas and those from bone are called osteosarcomas. Blood forming (haemopoietic), nerve and lymphatic tissue produce a variety of malignant tumours such as leukaemias, gliomas and Hodgkin's disease respectively.

Malignant tumours spread in three different ways. (1) By *direct invasion* and infiltration of surrounding structures. (2) By *lymphatic spread*, the chief way in which the carcinomas spread; their cells may be carried along the lymphatics with the lymph or they may actually grow along the lymph vessels. The regional lymph nodes are often affected by secondary growths (metastases) as they filter the lymph, and malignant cells arrested in them may continue to proliferate. (3) By the *blood stream*. Fragments of tumour may enter the veins draining the area in which the tumour is growing; they are carried in the blood stream and are likely to be held up in the next capillary vessels they meet. In the case of intestinal growths these will be the capillaries of the portal circulation in the liver, and hepatic metastases commonly occur in stomach and large bowel cancers. Venous blood from the kidneys, breasts and limbs will pass through the right side of the heart and the first capillaries that may arrest malignant cells will be in the lungs, so that pulmonary metastases may arise. Blood stream spread is usually a late feature of carcinomas but it is the chief method of dissemination in sarcomas.

Many malignant tumours are amenable to treatment with radiotherapy, which is often combined with surgery. The reason why the regional lymph nodes require treatment in the carcinomas will be appreciated from the foregoing, and in both carcinomas and sarcomas radiography of the chest is frequently performed to exclude the presence of bloodborne metastases.

5

Bones. The Skeleton. Joints

BONES

Bones are usually classified according to their shape into long, short, flat, irregular and sesamoid.

The *long bones* are found in the limbs and each is composed of a tubular shaft of compact and spongy bone with a central medullary cavity and expanded ends; examples are the femur, radius and metatarsals.

The *short bones* such as those of the carpus and tarsus combine strength with compactness and consist of a thin cortical layer surrounding spongy bone.

The *flat bones* may be mainly protective in function, for example, the vault of the skull, or, like the scapulae they may provide broad surfaces for muscle attachments. They usually consist of two tables of compact bone with a layer of spongy bone between.

The *irregular bones* such as the vertebrae consist of a relatively thin cortical layer surrounding spongy bone.

The *sesamoid bones* are found in muscle tendons in the vicinity of joints. The patella, the fabella and the small bones seen in the radiograph in the region of the head of the first metatarsal are examples of such bones.

DESCRIPTIVE TERMS USED IN OSTEOLOGY

Canal or meatus, a tunnel in bone.

Condyle, a smooth rounded projection.

Epicondyle, a projection above a condyle, e.g. the epicondyles of the humerus.

Facet, a small articular surface.

Foramen (pl. foramina), a hole perforating a bone, e.g. the foramina in the base of the skull.

Fossa, a depression in a bone, e.g. the olecranon fossa.

Lamina, a thin plate of bone, e.g. the lamina of a vertebra.

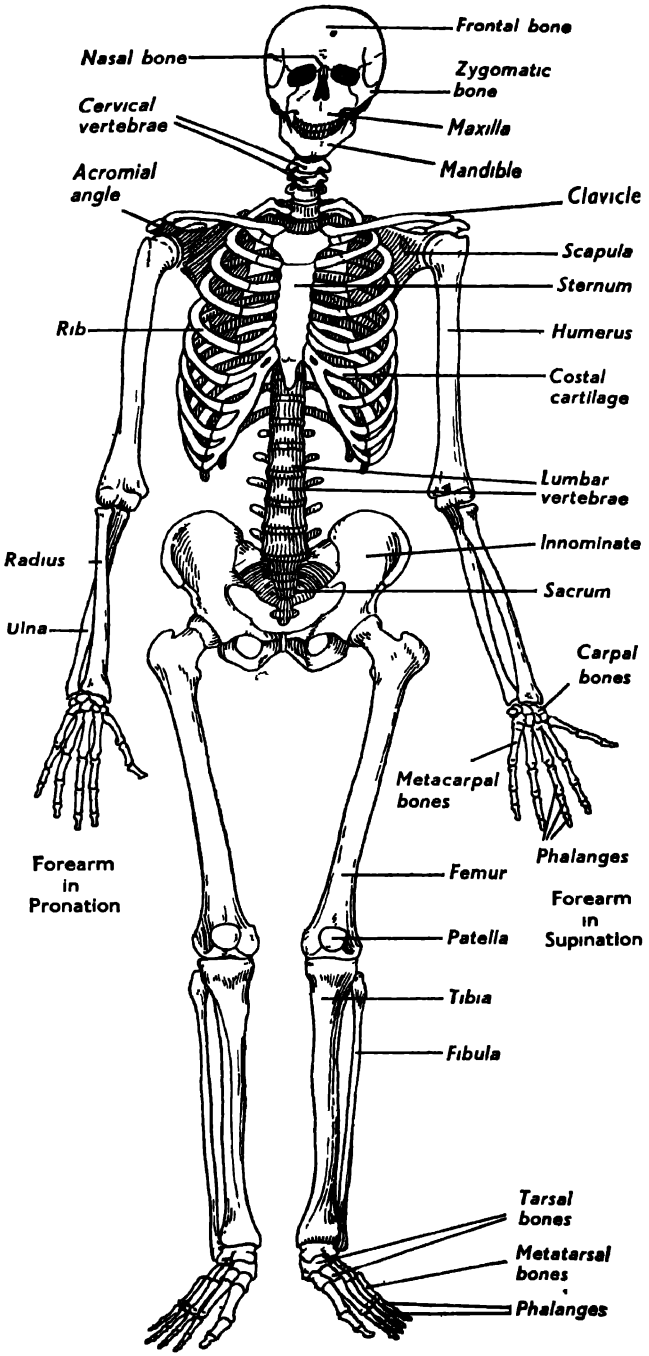


Fig. 5.1 The bony skeleton.

Meatus, see canal. (The plural of this word is also meatus but meatuses is used in this book.)

Process, a projection from a bone, e.g. the spinous process of a vertebra.

Tubercle, tuberosity and trochanter, broad rough elevations, e.g. the greater and lesser trochanters of the femur.

THE SKELETON

The skeleton may be divided into the *axial skeleton* comprising the skull, the hyoid, the ribs, the sternum and the vertebral column, and the *appendicular skeleton* which consists of the bones of the limb girdles and limbs.

The Functions of the Skeleton

(1) It provides a framework for the body.

(2) It provides attachments for muscles and ligaments.

(3) It protects internal organs, thus the ribs protect the lungs, the vertebrae protect the spinal cord and the skull protects the brain.

(4) It contains the bone marrow in which the blood corpuscles are formed.

(5) It provides a storehouse for calcium.

JOINTS

A joint or articulation occurs where two or more bones meet. The structure of a joint depends on whether or not it is designed to allow movement to occur. Joints may be classified as fibrous, cartilaginous and synovial.

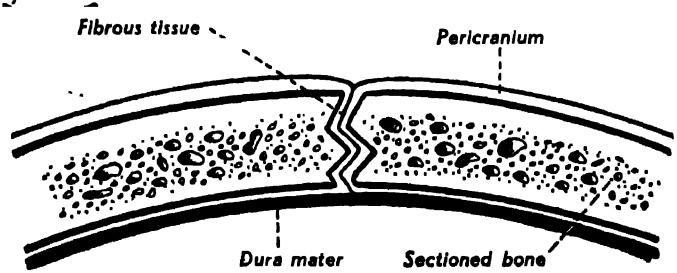


Fig. 5.2 A suturnal (fibrous) joint.

Fibrous joints are found between bones at junctions at which no significant movement is allowed to occur. Examples of such joints are the sutures of the skull, the inferior tibiofibular joints and the joints between the teeth and the sockets.

Cartilaginous joints allow a slight or very slight amount of move-

ment and the joint is more complex than the fibrous joint, there being a fibrocartilaginous plate between the two bone ends which are both covered with fibrocartilage. The external surface of the joint is reinforced by ligaments which connect the bones. Examples of cartilaginous joints are the pubic symphysis and those between the bodies of the vertebrae where the intervertebral discs are situated.

Synovial joints, with few exceptions, allow a very free range of movement. All the joints of the extremities with the exception of the inferior tibiofibular joints are examples of this group. All the synovial joints are constructed on the same basic plan and it will help the student in his studies if he bears this in mind.

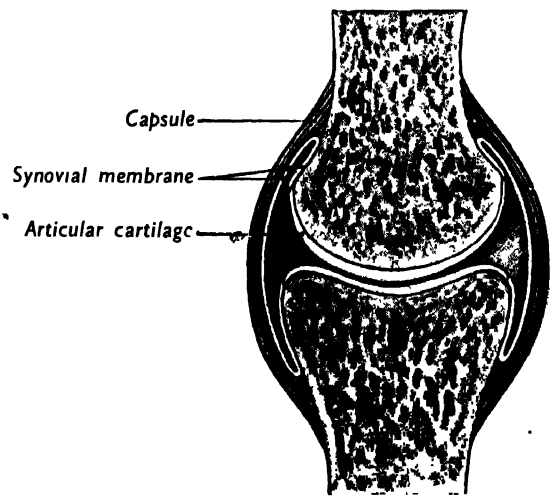


Fig. 5.3 A typical synovial joint.

THE STABILITY OF SYNOVIAL JOINTS

Certain spinal articulations, the temporomandibular joints and the joints of the extremities have to combine freedom of movement with stability; this is achieved by several factors: (1) The *shape* of the bones and cartilages forming the joint, e.g. the ball and socket form of the hip joint. (2) The *capsule* which is reinforced by accessory ligaments. In hinge joints such as the knee the ligaments on either side of the joint are very strong whereas the capsule, though strong, is lax anteriorly and posteriorly to allow flexion and extension to occur. (3) *Muscular action*, the normal tone of strong muscles surrounding joints keeps the bones in normal relationships and relieves undue strain falling on the capsule and ligaments. Some muscles,

e.g. those of the shoulder, actually partly blend with the joint capsule and so reinforce it.

The student should, in due course, compare the shoulder and hip joints. The shoulder joint is a non-weight bearing joint with a much wider range of movement than the hip joint. Strength of the shoulder joint has been sacrificed to a certain extent for mobility. The glenoid fossa is very shallow and is deepened only to a minor extent by the cartilaginous glenoid labrum whereas the acetabulum is already deep and is further deepened by the acetabular labrum. The capsule is not as strong as in the hip and is relatively weak in its inferior part. Muscular action, particularly of the short muscles connecting the scapula to the humeral head, is extremely important in preventing dislocation but these muscles are less powerful than those around the hip. Nevertheless dislocation of the shoulder is a common injury and is usually a downward and forward dislocation of the head through the weakest part of the capsule. The hip is very rarely dislocated and then usually only by a very severe injury.

CHARACTERISTICS OF SYNOVIAL JOINTS

(1) The articular surfaces of the bones are covered by hyaline cartilage which constitutes the *articular cartilage*. The shapes of these surfaces, in a large measure, determine the movements occurring at the joints.

(2) The joint is surrounded by a ligamentous *capsule* of fibrous tissue.

(3) The capsule is lined by *synovial membrane* which does not cover the articular cartilage but blends with its margins. The membrane secretes traces of lubricating fluid and also covers certain intra-articular structures.

(4) The capsule of the joint is strengthened by additional *ligaments* which in hinge-joints are particularly strong medially and laterally.

(5) Some joints have *intra-articular structures*, e.g. the menisci and cruciate ligaments of the knees.

(6) The joint has a certain range of *movement* (p. 35).

(7) The joint receives a *nerve supply* and has *vascular connections*.

(Note: When describing a particular synovial joint the student should also indicate important relations of the joint and the main muscles responsible for its movements.)

CLASSIFICATION OF SYNOVIAL JOINTS

The synovial joints are classified according to the type of movement they allow and in the principal varieties which are listed

below it will be seen that many of the terms are self-explanatory.

(1) *Hinge-joint.* In this type of joint, of which the elbow and knee are examples, movement occurs in one plane about the transverse axis of the limb.

(2) *Pivot-joint.* In these joints movement (i.e. rotation) occurs about the longitudinal axis of the limb; examples are the superior radio-ulnar and the atlanto-axial joints.

(3) *Ball-and-socket joint.* These have a very wide range of movement; the hip and shoulder are of this variety.

(4) *Condyloid* and *saddle-joints.* An example of the former is the wrist and of the latter the carpometacarpal joint of the thumb. A variety of movements is possible.

(5) *Plane joint.* This variety allows gliding movement only. Examples are the joints between the articular facets of the vertebrae and those between the carpal and tarsal bones.

MOVEMENTS OF SYNOVIAL JOINTS

Gliding movements occur at many joints and are the only movements possible at the carpal and tarsal joints. *Flexion* is bending at the joint and *extension* is the opposite movement – straightening the joint. *Adduction* implies movement towards the median plane of the body, or, in the case of the digits, towards the middle finger or toe; *abduction* is the opposite movement, i.e. away from the midline or middle finger (toe) as the case may be. *Circumduction* is the movement at the shoulder or hip joints when the limb is moved in a circular fashion, e.g. the arm in overarm bowling. *Rotation* is movement round the longitudinal axis and is illustrated by the movement of the arm when the forearm is moved from side to side with the elbow flexed to a right angle.

Pathological Considerations

An interruption in continuity of a bone is called a *fracture* (i.e. a break). In childhood incomplete or greenstick fractures may occur and, as their name suggests, they bear a resemblance to incompletely broken stalks. A compound fracture is one in which the break in the bone communicates with the surface of the body through a wound in the overlying skin and soft tissues; it is very liable to infection. A fracture associated with other injuries such as a puncture of the pleura or rupture of the spleen by a broken rib is called a complicated fracture and one in which the bone is shattered into several fragments is said to be comminuted.

An epiphysis may slip (i.e. become displaced) as a result of an injury and after reduction it may fuse prematurely with the shaft leading to interference in growth in length of the bone.

A *dislocation* is an abnormal displacement of the bones taking part in the formation of a joint. Such a condition may be congenital, for example a child may be born with dislocation of one or both hips; it may be pathological as a result of ligamentous softening or destruction by disease or it may be the result of injury, when it is said to be traumatic.

Osteitis is a bacterial infection of bone and it may be acute or chronic. If the latter the bone may become very dense and suitable adjustment of technical factors is likely to be required before satisfactory radiographs can be obtained.

Arthritis is inflammation of a joint but the term also includes degenerative conditions such as *osteoarthritis*. *Rheumatoid arthritis* is an intractable inflammatory condition affecting many joints, especially the small ones of the hands and feet. *Ankylosing spondylitis* somewhat resembles rheumatoid arthritis but it involves the sacro-iliac joints and the spine and leads to fixation of the vertebral column and thorax. During the painful stages of this condition radiotherapy may be required to relieve symptoms.

Tumours of bone may be innocent or malignant. The latter may be either primary, for example, *osteogenic sarcoma*, or metastatic from such primary growths as carcinoma of the breast or prostate.

The Healing of Fractures

During the first few days after a bone has been fractured a blood clot fills the gap at the site of the injury. The clot is then invaded by connective tissue and newly formed blood capillaries and is then called *callus*. Within a week islands of new bone appear and these enlarge and coalesce until the fracture is eventually united by bone which lacks the normal architecture of lamellae, Haversian canals, etc. This woven bone, as it is called, is gradually replaced by lamellar (mature) bone. The fracture is usually united sufficiently soundly for careful use of the part at the stage of union by woven bone.

Various factors influence the rate of repair of fractures, union being fastest in the infant. Certain bones such as the scaphoid and lower one-third of the tibia often take a very long time to unite; this is probably due to impairment of the blood supply of one fragment. Failure to secure adequate immobilization may also delay union.

6

The Bones and Joints of the Skull. The Hyoid

THE SKULL

The skull consists of the cranium and the facial bones.

THE CRANIUM

The cranium is a bony box containing the brain and its membranes. It is made up of eight bones, the frontal, occipital, sphenoidal, ethmoidal and the paired temporal and parietal bones. The bones of the vault of the skull are flattened and consist of an inner and an

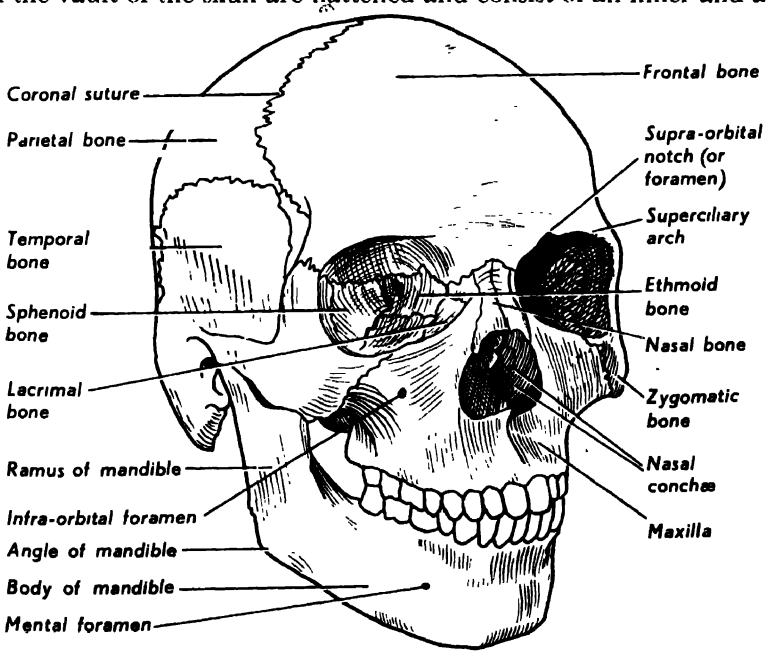


Fig. 6 1 The skull.

outer table between which is a marrow-filled layer known as the *diploë*. The lower surface of the cranium is called the base of the skull.

The **frontal bone** forms the forehead and most of the roof of each orbit. From the supraorbital margin a thin plate extends back into each orbit forming its roof. The two tables are separated above the nose and inner parts of the orbits by a pair of irregular shaped cavities, the *frontal air sinuses*, containing air and communicating with the nose.

The **parietal bones** form the sides and roof of the cranium and each has four borders where articulation with neighbouring bones occurs at the *sutures*. Certain important vascular markings are

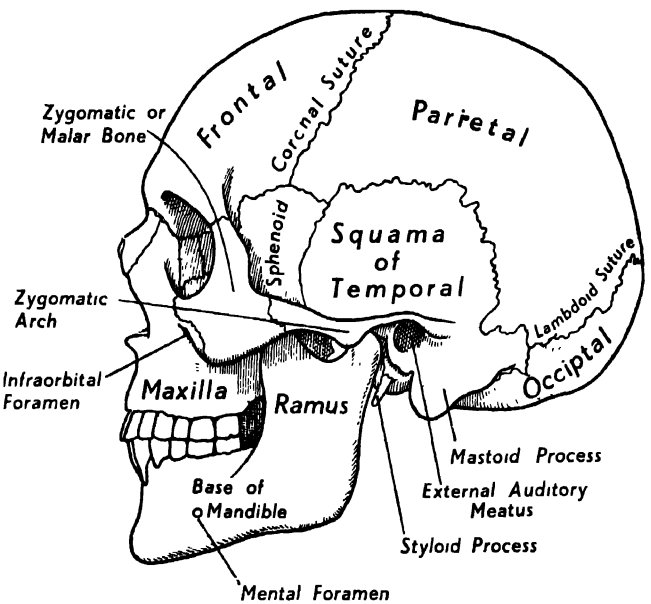


Fig. 6.2 Lateral aspect of the skull.

visible on the inner surface of the parietal bones and they are often clearly seen in radiographs; these are the grooves for the anterior and posterior branches of the middle meningeal artery.

The **temporal bones** form the lower parts of the sides and part of the base of the skull. They are frequently studied radiographically because of the important structures they contain, e.g. the ear, the mastoid air cells and the auditory nerve. Each bone consists of five parts, the squamous, petrous, mastoid and tympanic portions and the styloid process.

The *squamous part* is a thin sheet of bone which takes part in the

formation of the side of the cranium. From its lower part the *zygomatic process* projects forwards to join a process from the malar bone to form the *zygomatic arch.* Below the root of the zygomatic process is the mandibular fossa which articulates with the mandible forming the *mandibular joint* and behind this lies the *external auditory meatus.*

The *mastoid part* is the most posterior portion of the bone and the *mastoid process* projects downwards from it. In this process are the mastoid air cells; these are epithelium lined cavities which communicate with the *tympanic (or mastoid) antrum*; a larger space whose epithelial lining is continuous with the lining of the middle ear.

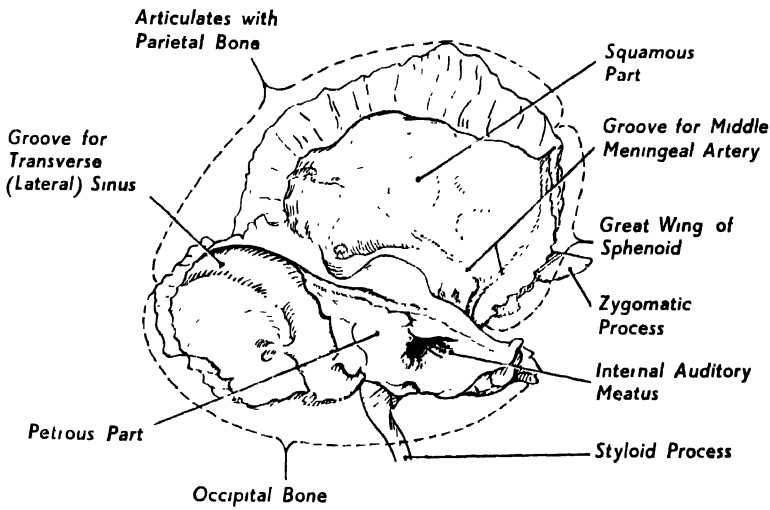


Fig. 6.3 Internal aspect of the left temporal bone.

Infection reaching the middle ear from the pharynx by way of the auditory tube (p. 145) may spread to the mastoid air cells.

The *tympanic part* lies in front of the mastoid process and forms the floor of the external auditory meatus. The *styloid process* projects downwards and forwards from the under surface of this part of the bone.

The *petrous part* of the temporal bone is an important component of the base of the skull where it is wedged in between the sphenoidal and occipital bones. The organs of hearing and equilibrium lie within it and passing medially from the internal ear is a canal about ½ inch (1 centimetre) in length, the *internal auditory meatus*, which transmits the auditory and facial nerves.

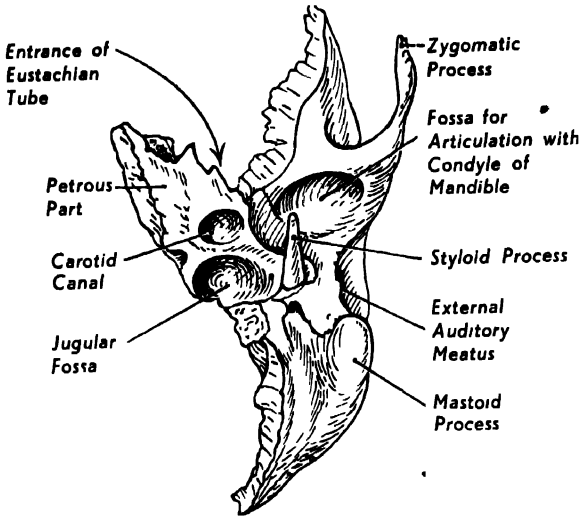


Fig. 6.4 Under surface of the left temporal bone.

The **occipital bone** forms the posterior part of the cranium. It is pierced by the *foramen magnum* through which the spinal cord passes from the brain. On each side anterolateral to this foramen are the

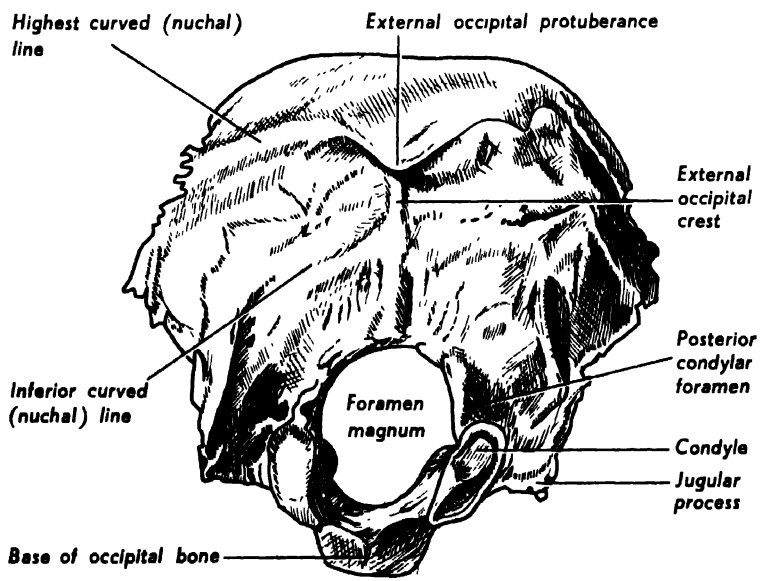


Fig. 6.5 Outer surface of the occipital bone.

occipital condyles for articulation with the atlas (first cervical vertebra). The flattened portion behind the foramen magnum is called the *squamous part* and in front of the foramen is the *basilar portion* of the occipital bone which fuses anteriorly with the sphenoidal bone.

The **sphenoidal bone** is situated at the base of the skull. It is said to resemble a bat in flight and it consists of a central *body* from which project laterally on each side a *greater* and a *lesser wing*.

The body is hollowed out by the large *sphenoidal air sinus* and its upper surface bears a deep depression known as the *sella turcica* (lit. Turkish saddle) in which the pituitary gland (or hypophysis) lies. The sella turcica is bounded anteriorly by the *optic groove*, at

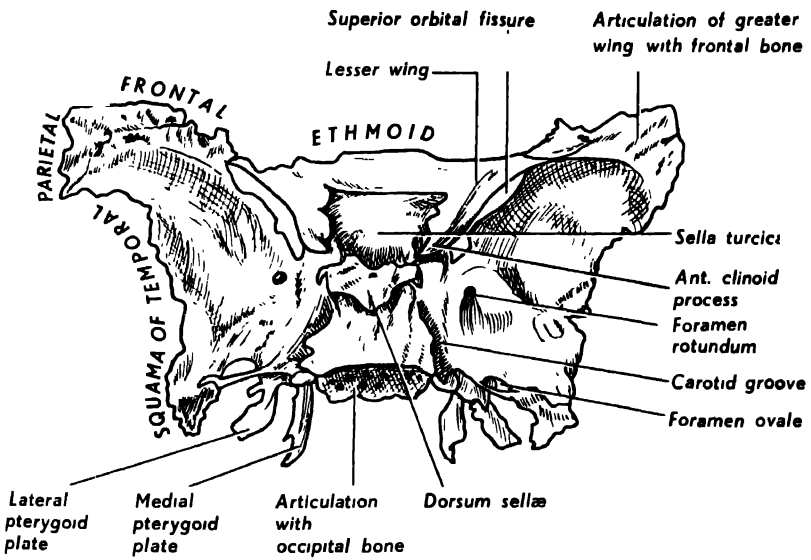


Fig. 6.6 Sphenoidal bone, viewed from above.

the lateral ends of which are the *optic foramina* through which the optic nerves pass. The posterior boundary of the sella turcica is formed by a plate of bone, the *dorsum sellae*, from which project the *posterior clinoid processes*. During the first two decades the posterior surface of the sphenoidal bone is joined to the basal part of the occipital bone by a plate of cartilage and this junction is often visible in radiographs (the spheno-occipital suture).

Each greater wing of the sphenoidal bone extends laterally forming the anterior part of the middle cranial fossa and part of the side wall of the cranium between the frontal bone and the squamous

portion of the temporal bone. There are several foramina in the greater wing through which important nerves and blood vessels pass (see p. 43).

The lesser wings are short, pointed and triangular and project laterally from the upper and anterior part of the body of the bone. Both greater and lesser wings take part in the formation of the roof and outer wall of the orbit and between the two wings is a gap known as the *superior orbital fissure* through which nerves and blood vessels pass to the muscles of the eye, etc. The *anterior clinoid processes* project from the posterior surface of the medial ends of the lesser wings and the *optic canals* perforate the base of each lesser wing.

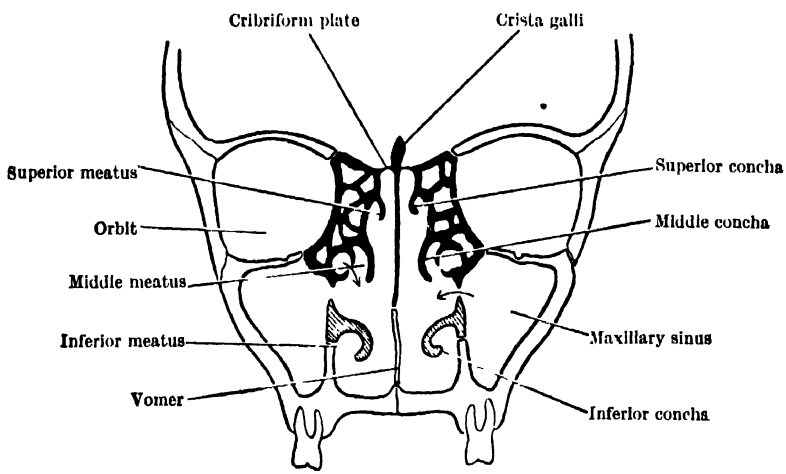


Fig. 6.7 Diagrammatic coronal section through the facial part of the skull to show the essential construction of the bony nasal cavity and its relation to adjacent structures.

These canals lead directly from the optic foramina to the orbits; each is from 4 to 8 mm. in length and about 4 mm. in diameter. They are directed forward and outwards making an angle of about 30° with the sagittal plane and they are of great radiographic importance.

The **ethmoidal bone** is a light spongy structure consisting of four parts, a horizontal perforated plate called the cribriform plate, a perpendicular plate and two labyrinths or lateral masses.

The *cribriform plate* forms the medial portion of the floor of the anterior cranial fossa and has projecting upwards a crest, the *crista galli*. The *perpendicular plate* projects downwards approximately in the sagittal plane forming part of the nasal septum. The *labyrinths*,

in which are situated the ethmoidal air cells, project down from the cribriform plate on each side and form part of the lateral wall of the nose.

THE CRANIAL FOSSAE

If the skull-cap and the brain and its membranes are removed the interior of the base of the skull can be studied. It is usual to describe three cranial fossae: an anterior, a middle and a posterior.

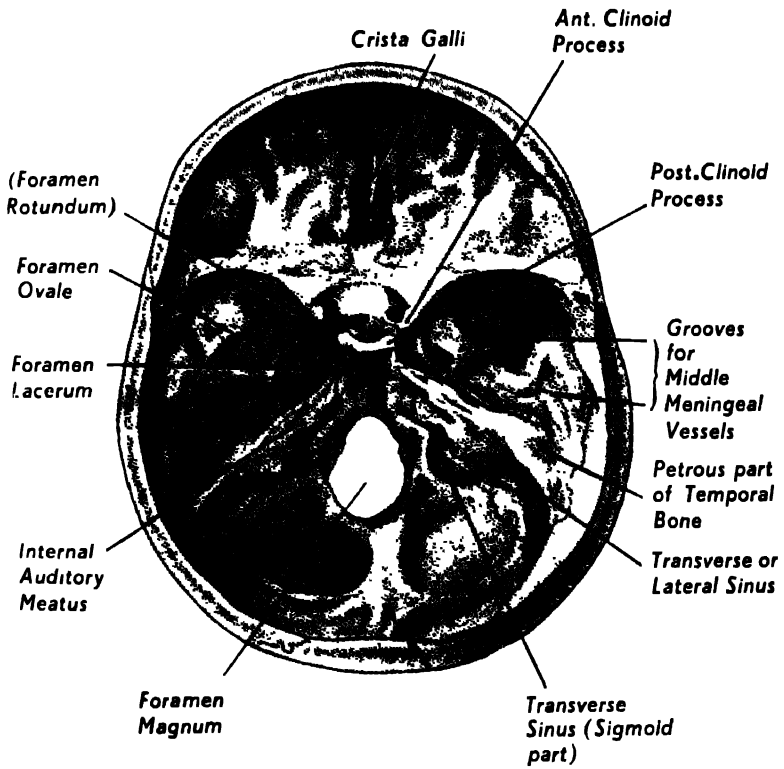


Fig. 6.8 The internal surface of the base of the skull.

(1) The *anterior cranial fossa* extends from the front of the base of the skull to the posterior margin of the lesser wings of the sphenoidal bone and the anterior margin of the optic groove. The floor is formed by the orbital plates of the frontal bone, between these by the cribriform plate of the ethmoidal bone and posteriorly by the sphenoidal bone. The cribriform plate contains many tiny perforations by which the olfactory nerves pass from the nose to the interior

of the skull. The anterior cranial fossa contains the frontal lobes of the brain.

(2) The *middle cranial fossa* is bounded anteriorly by the posterior border of the anterior fossa, i.e. the lesser wings of the sphenoidal bone and the anterior margin of the optic groove. The posterior border of the fossa is formed medially by the dorsum sellae and laterally by the superior margins of the petrous portions of the temporal bones. The lateral boundaries consist of the squamous parts of the temporal bones, the lower parts of the parietal bones and the lateral parts of the greater wings of the sphenoidal bones. In the middle of the floor is the sella turcica and on either side are the greater wings of the sphenoidal and upper surfaces of the petrous portions of the temporal bones. Between the greater and lesser sphenoidal wings are the *superior orbital fissures*. In the floor of the middle fossa there are several foramina on each side; the most important of these are the *foramen rotundum* and the *foramen ovale* for branches of the fifth cranial nerve, the *foramen spinosum* for the middle meningeal artery and the *foramen lacerum* which lies at the apex of the petrous part of the temporal bone. The foramen lacerum is occluded by cartilage below but its upper part transmits the internal carotid artery. The groove for the middle meningeal artery and vein runs forwards and laterally from the foramen spinosum for about ¾ inch (2 centimetres) where it divides into an anterior and a posterior branch. The middle fossa contains the temporal lobes of the brain and, within the sella turcica, the pituitary gland.

(3) The *posterior cranial fossa* is bounded anteriorly by the petrous parts of the temporal bones and near the midline by the dorsum sellae of the sphenoidal bone. Posteriorly the fossa is limited on either side by the transverse sulcus on the squamous portion of the occipital bone. An aperture in its floor, the *foramen magnum*, transmits the spinal cord and closely related to this are the *two jugular foramina* through which the internal jugular veins leave the skull. The openings of the internal auditory meatuses or canals which transmit the auditory and facial nerves will be seen in the posterior aspect of each petrous portion of the temporal bones. The parts of the brain known as the cerebellum, the pons and the medulla lie in the posterior cranial fossa.

THE CRANIAL SUTURES

Fibrous joints, known as *sutures*, unite the bones of the skull. These joints permit a certain amount of moulding to occur during birth;

some are obliterated during growth but many persist throughout adult life and are visible in radiographs. Small bones, called Wormian bones, are often found in the sutures.

The main sutures are (1) the *sagittal* between the two parietal bones, (2) the *coronal* between the frontal bone and the anterior borders of the parietal bones, (3) the *squamosal* between the squamous part of the temporal bone and the inferior border of the parietal bone on each side and (4) the *lambdoid* between the occipital bone and the posterior borders of the parietal bones.

At birth the bones of the skull are incompletely ossified and there are gaps between them which are filled in by membrane. These gaps

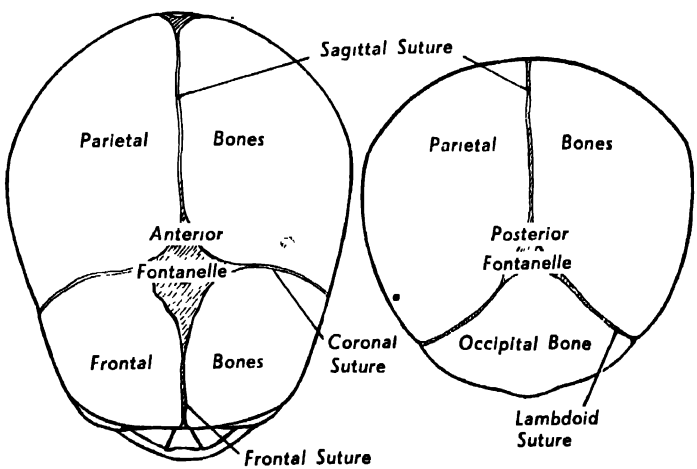


Fig. 6.9 The foetal skull from above (left) and from behind (right).

are called *fontanelles* and the largest are found at the two ends of the sagittal suture. The anterior fontanelle is at the junction of the frontal with the two parietal bones and the posterior is at the junction of the occipital with the parietal bones. The anterior fontanelle closes by about 18 months of age and the posterior by about 6 months.

THE FACIAL BONES

The bones of the face consist of the two upper jaws or *maxillae*, the two cheek or *malar bones*, the two *nasal* bones, the *mandible* or lower jaw and others which take part in the formation of the medial wall of the orbit, the nasal septum and the hard palate.

The **maxillae** or upper jaws contribute to the formation of the floors of the orbits, the lateral walls of the nose and the roof of the mouth. The teeth arise from the *alveolar processes* and a large cavity, the *maxillary sinus* or *antrum* occupies the body of each maxilla.

The **mandible** or lower jaw consists of a horizontal portion, the *body*, and two *ascending rami* (sing. ramus) which are bony plates projecting upwards from the ends of the body. The middle of the body is called the *symphysis* and from the upper end of each ramus two processes project, these are the pointed *coronoid process* anteriorly and the rounded *condyle* or head posteriorly which takes part in the formation of the mandibular joint. A canal known as the *mandibular*

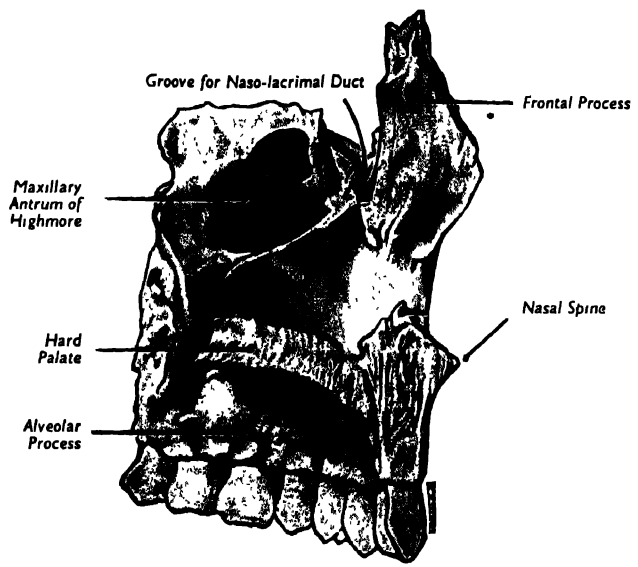


Fig. 6.10 The left maxilla, medial aspect.

or alveolar canal traverses much of the ramus and adjacent part of the body on each side; it carries nerves and vessels to the teeth of the lower jaws and ends anteriorly at the *mental foramen.*

The **mandibular** or **temporomandibular joint** is a synovial joint between the articular tubercle and mandibular fossa of the temporal bone above and the condyle of the mandible below. There is an *articular disc* within the joint which divides it into an upper and a lower cavity. Articular cartilage covers the joint surfaces and there are synovial membrane, a joint capsule and ligaments. The *movements* of the joint allow the mandible to be raised and lowered, to be carried forwards or backwards and to be moved

somewhat from side to side. When the mouth is opened, i.e. the mandible is lowered, the condyles and the articular disc move forwards out of the mandibular fossa on to the articular tubercles, the bony prominences in front of the fossae.

Immediately posterior to the mandibular fossae are the external auditory meatuses and this close relationship is of clinical importance.

The **orbits** are pyramidal cavities which contain the eyes, the ocular muscles, the optic nerves and the lacrymal (tear) glands. Their long axes diverge as they are traced forwards and each orbit has a roof, a floor and medial and lateral walls.

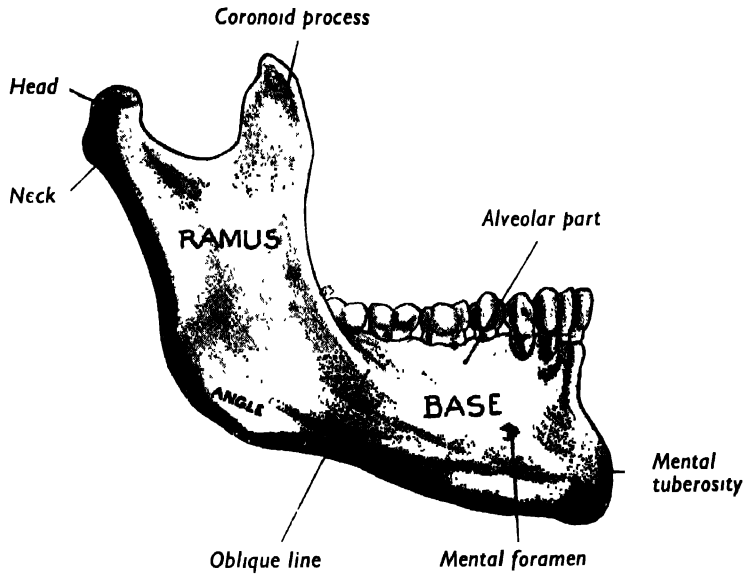


Fig. 6.11 The mandible. The right half viewed from the lateral side. (For Base read Body)

The *roof* consists of the orbital plate of the frontal bone and the lesser wing of the sphenoidal bone. The *floor* is formed by the upper surface of the maxilla. The *medial* wall is made up of several bones, including the lateral aspect of the labyrinth of the ethmoidal bone; the optic foramen lies posteriorly in this wall. The *lateral* wall consists of the malar bone anteriorly and the greater wing of the sphenoidal bone posteriorly. The posterior parts of the roof and lateral wall are separated by the superior orbital fissure and between the lateral wall and floor is the inferior orbital fissure.

The **nose** is the organ of smell and is divided into the *external nose*, a bony and cartilaginous structure which bears the nostrils or

anterior nares, and the *nasal cavity* which opens posteriorly into the nasopharynx through the *posterior nares*. A septum which lies approximately in the midline divides the nasal cavity into right and left halves.

The nasal cavity has a roof consisting of the cribriform plate of the ethmoidal bone (see Fig. 6.7), a floor formed by the hard palate, and lateral walls which consist principally of the medial surfaces of the maxillae below and the medial surfaces of the ethmoidal labyrinths above. These lateral walls are largely obscured



Fig. 6.12 Boundaries of the right orbit viewed from in front.

by the *conchae* or *turbinate bones* which project downwards and medially and to some extent warm and filter the incoming air. Beneath each concha is a passage called a *meatus*.

The *inferior concha* is a separate bone articulating with the nasal surface of the maxilla; beneath it is the *inferior meatus* into which opens the nasolacrymal duct, a bony canal connecting the orbit with the nasal cavity down which tears, the secretion of the lacrymal glands, may pass.

The *middle concha* projects from the nasal surface of the ethmoidal labyrinth and below it, into the *middle meatus*, open the maxillary antrum, the frontal sinus and the anterior and middle ethmoidal sinuses.

The *superior concha* also projects from the nasal surface of the

ethmoidal labyrinth and immediately below it is the *superior meatus*, into which the posterior ethmoidal sinus opens. Behind this is the spheno-ethmoidal recess with which the sphenoidal air sinuses communicate.

The **accessory nasal sinuses** are cavities in the bones in the neighbourhood of the nasal passages with which they communicate; they are lined by ciliated mucous membrane. They develop as out-pouchings from the nasal passages and are sufficiently well developed to be demonstrable in radiographs at 4 or 5 years of age.

They may be considered as *anterior* and *posterior groups*; the former open into the middle meatus of the nose and the latter into the

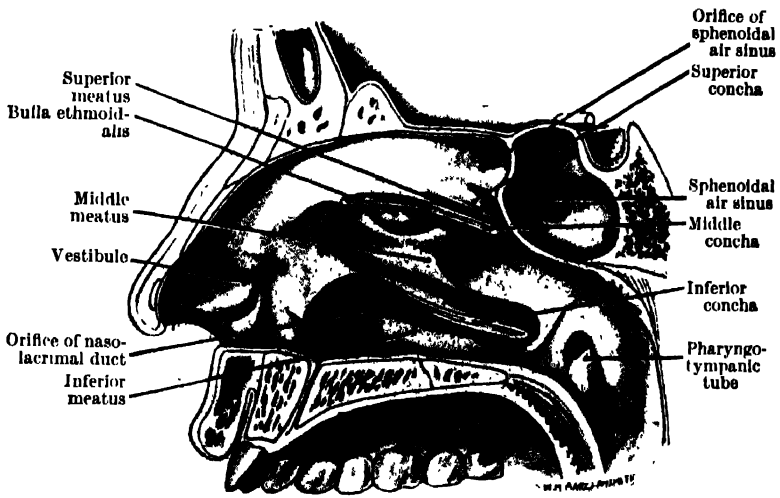


Fig. 6.13 The lateral wall of the right half of the nasal cavity, as seen after removal of the greater part of the conchae (after Sabotta).

superior meatus and into the spheno-ethmoidal recess. The anterior group consists of the two *maxillary antra*, the two *frontal sinuses* and the two *anterior* and *middle ethmoidal sinuses*. The posterior group comprise the two *posterior ethmoidal sinuses* and the two *sphenoidal sinuses*.

The *frontal sinuses* are situated one on each side of the midline and lie between the inner and outer tables of the frontal bone over the root of the nose and inner parts of the orbits. They vary considerably in size and are separated from each other by a bony septum. They drain into the middle meatus of the nose.

The *maxillary sinuses* (or *antra*) are two large cavities, one in each upper jaw. Each is roofed by the orbital surface of the maxilla and



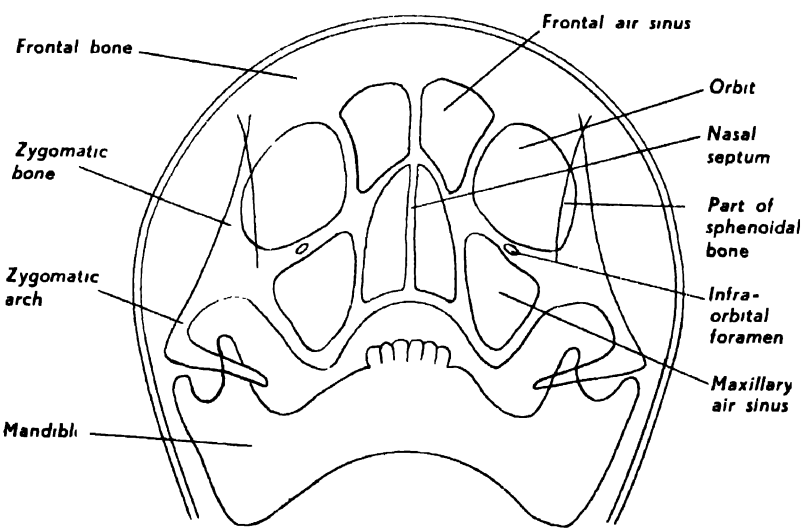


Fig. 6.14 (*a*) Radiograph showing the accessory nasal sinuses;
(*b*) Line drawing of (*a*).
The ethmoidal and sphenoidal sinuses are not shown in this diagram.

its floor is formed by the alveolar process of the maxilla from which the roots of the molar and premolar teeth may project into the sinus. The medial wall forms part of the lateral wall of the nose and is perforated by the aperture which connects the antrum to the middle meatus. The anterior and posterior walls of the maxillary sinus are the inner aspects of the facial and posterior surfaces of the maxilla respectively.

The *ethmoidal sinuses* are situated in the labyrinths of the ethmoidal

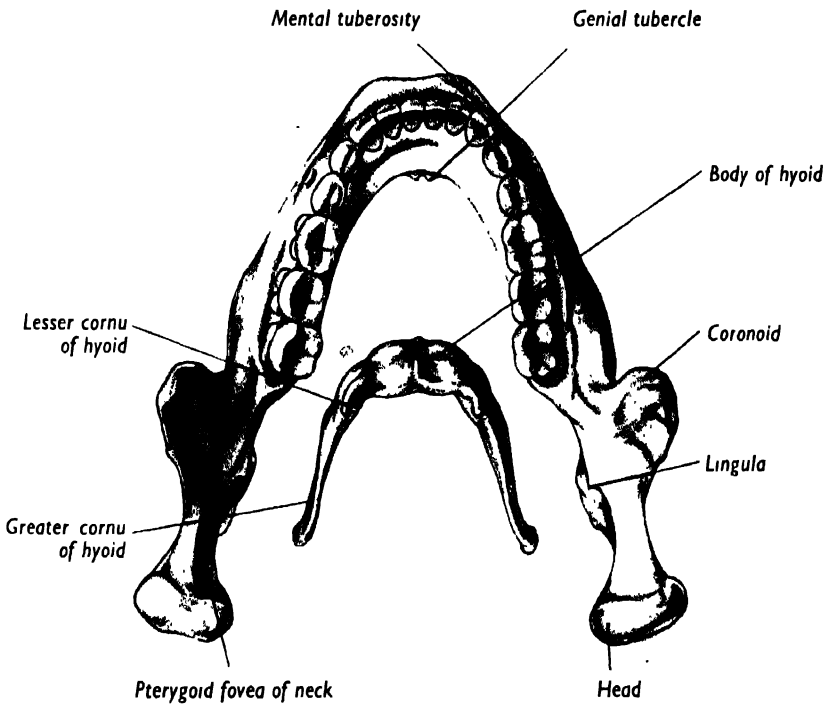


Fig. 6.15 The mandible and hyoid from above.

bones and so are placed between the nasal passages and the orbits. They consist of a number of thin-walled bony cavities or cells lined with mucous membrane which are arranged in anterior, middle and posterior groups. The anterior and middle ethmoidal cells drain, like the frontal sinuses, into the middle meatus of the nose and the posterior cells drain directly into the superior meatus.

The two *sphenoidal sinuses* occupy the body of the sphenoidal bone and are separated from each other by a thin bony septum. The sella turcica is above them and they communicate with the nasopharynx by apertures in their anterior walls.

THE HYOID

The hyoid is a small bone lying in the anterior part of the neck between the mandible and the larynx. It consists of a body, two greater and two lesser cornua. It is suspended from the styloid processes of the temporal bones by the stylohyoid ligaments and gives origin to the muscles of the tongue.

RADIOGRAPHIC APPEARANCES OF THE SKULL

THE ANTERIOR RADIOGRAPH

The diploic structure of the skull is visible in this radiograph and the sagittal, coronal and lambdoid sutures may be seen. The frontal



Fig. 6.16 Radiograph of skull in the anterior projection.

sinuses and the orbits produce characteristic appearances and, unless the ray is directed towards the feet, the petrous portions of the temporal bones are superimposed on the lower halves of the orbits.

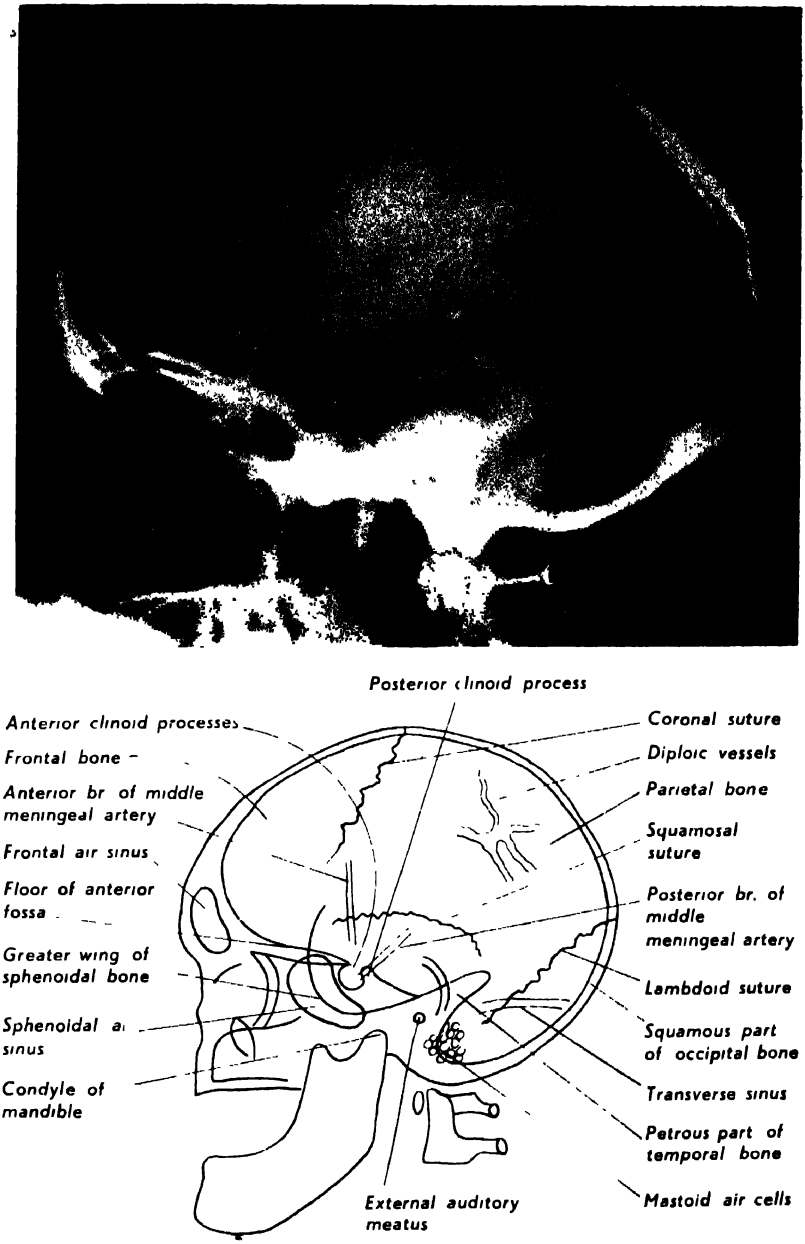


Fig. 6.17 (*a*) Radiograph of skull. Lateral projection. Note calcified pineal body (of no pathological significance). (*b*) Line drawing of structures seen in lateral radiograph of skull. The markings on one side only are shown.

In the upper parts of the orbital shadows the lesser wings of the sphenoidal bones are seen and the ethmoidal and sphenoidal air sinuses and the nasal cavity produce a composite shadow. On either side of the nose are the maxillary sinuses and projecting into the nasal cavity from its lateral walls are the conchae.

THE LATERAL RADIOGRAPH

In this radiograph the attention is usually directed to the bones of the vault and the bones of the base. The facial bones are superimposed on each other and are not usually the object of special study in this projection.

The *vault* varies in thickness; the squamous parts of the temporal and occipital bones are usually thinner and therefore more transradiant than the parietal and frontal bones which, because of their greater opacity, appear whiter in the radiograph. Where the ray strikes the vault tangentially the two tables and the intervening diploë may be apparent. The coronal, squamosal and lambdoid sutures will be demonstrated but the sagittal, of course, will not be seen.

Certain markings will be visible in the vaults; the convolution of the brain may produce '*digital markings*' which are depressions on the inner table and are often seen in children. Several markings caused by blood vessels may be seen and these are listed below.

Vascular markings shown in the radiograph of the vault of the skull:

(1) the anterior branches of the middle meningeal vessels are responsible for the grooves which cross the squamous parts of the temporal bones and the posterior branches may be seen running backwards across the parietal bones at a lower level.

(2) The groove for the transverse sinus, a large vein within the skull, may appear as a transverse band $\frac{1}{2}$ inch (1 centimetre) in width crossing the occipital bone.

(3) Certain veins run in the diploic space and may be seen as branching dark lines which are usually most marked in the parietal bones.

(4) The arachnoid granulations (see Chapter 17) may produce small indentations of the inner table of the skull, usually on either side of the midline.

Other structures which may be seen superimposed on the vault of the skull include:

(1) The pinna of the ear, which may produce an arc-like shadow above the petrous portions of the temporal bones.

(2) The pineal body, a single midline structure in the brain (p. 240), which may become calcified and will then be visible in the radiograph as a shadow about $\frac{1}{8}$ inch (2 millimetres) in diameter, approximately 1 inch (2.5 centimetres) above and $\frac{1}{2}$ inch (1 centimetre) behind the external auditory meatus.



Fig. 6.18 (*a*) Radiograph of the skull in the superior (SMV) projection.

(3) The posterior parts of the choroid plexuses of the lateral ventricles (p. 244, Chapter 17) frequently calcify and then show as a

shadow or pair of shadows about $\frac{3}{4}$ inch (2 centimetres) behind the site at which the pineal body will be seen if calcified.

The *base of the skull* is seen in profile in this projection. Anteriorly the frontal sinuses expand the diploic space at the base of the frontal bone; behind them the orbital plates of the frontal bones, which roof in the orbits, are continuous with the lesser wings of the sphenoidal bones, from which the anterior clinoid processes project. The cribriform plate of the ethmoidal bone may be identified below the orbital plates of the frontal bones.

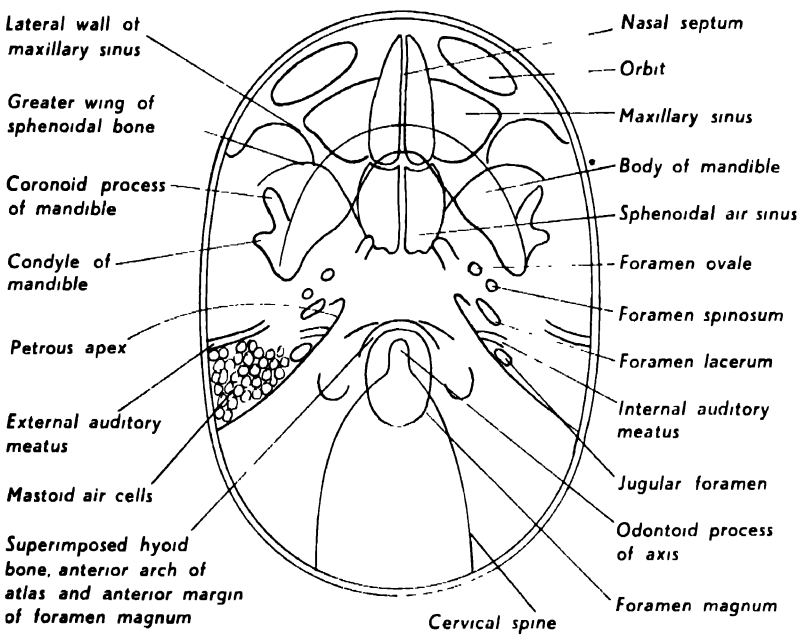


Fig. 6.18 (*b*) Line drawing of structures seen in the radiograph taken in this projection.

The floor of the middle fossa in its anterior portion, where it is formed by the greater wings of the sphenoidal bones, produces curved white lines (or a single line if the two sides are superimposed) parallel with the floor of the sphenoidal sinus as it arches upwards to the lower part of the coronal suture of each side.

The sella turcica (pituitary or hypophyseal fossa) is seen as a round or oval depression above the sphenoidal air sinus; above it

in front are the anterior clinoid processes and behind are the posterior clinoid processes and dorsum sellae.

Between the middle and posterior cranial fossae is a dense white triangular shadow caused by the superimposition of the two petrous parts of the temporal bones. A transradiant area in this shadow is caused by the external auditory meatus and behind this the mastoid air cells will be seen as an area of variable size, honeycombed with transradiancies. In front of the external auditory meatus the mandibular joint is shown.

THE SUPERIOR (SUBMENTOVERTICAL) RADIOGRAPH

Anteriorly the facial bones and the maxillary sinuses are superimposed upon the anterior cranial fossa. The lesser wings of the sphenoidal bones separating the anterior from the middle cranial fossa are seen as two curved lines convex forwards. In the floor of the middle fossa, on each side, the foramina lacerum, ovale and spinosum will be identified. The petrous portions of the temporal bones intervene between the middle and posterior fossae and the shadows of the atlas vertebra and odontoid process of the axis are superimposed on the foramen magnum.

7

The Bones and Joints of the Vertebral Column and Thorax

THE VERTEBRAL COLUMN

The vertebral column is the central axis of the body and consists of irregular bones called *vertebrae*. It protects the spinal cord, and supports the weight of the head and trunk which it transmits to the lower limbs.

The vertebrae, with certain exceptions, are separate bones bound to each other by ligaments and capable of a certain amount of movement because of the intervening joints. They are grouped according to the region in which they lie as seven *cervical*, twelve *thoracic*, five *lumbar*, five *sacral*, and four *coccygeal*. Although there is considerable variation in the appearance of the vertebrae in the different regions they are all built up from the same basic plan, but the first two cervical and the sacral and coccygeal vertebrae show a greater departure from this plan than do those of the other regions.

Essentially a typical vertebra consists of a rounded *body* anteriorly with flattened upper and lower surfaces and a *vertebral arch* posteriorly; these enclose a space through which runs the spinal cord, it is known as the *vertebral* or *spinal foramen* or the *neural canal.*

The *vertebral* or *neural arch* consists of a pair of *pedicles* which constitute the sides of the arch and a pair of *laminae* which roof in the arch posteriorly. Seven processes spring from the arch; in the midline projecting from the junction of the two laminae is the *spinous process*; arising from the junctions of the pedicles with the laminae on each side are the *transverse processes*, and directed upwards and downwards respectively are the *superior* and *inferior articular processes* on which are the facets for the posterior intervertebral articulations. Intervening between the upper and lower surfaces of adjacent vertebral bodies are the *intervertebral discs*; the gaps between the pedicles and neighbouring vertebrae are called the *intervertebral foramina* and the spinal nerves and vessels pass through them.

THE CERVICAL VERTEBRAE

The seven cervical vertebrae differ somewhat from the basic plan and this departure is most extreme in the first two. The first cervical vertebra is called the *atlas* and it has an *anterior arch* in place of a body. The second, called the *axis*, has projecting upwards from its body a stout peg, the *odontoid process*.

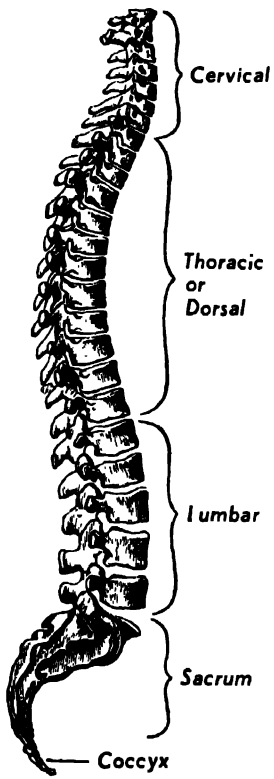


Fig. 7.1 The vertebral column.

Lateral aspect of the vertebral column showing normal curves. *Note*: The cervical and lumbar regions show a slight forward convexity and the thoracic and sacral regions show a backward convexity.

The chief characteristics of the cervical vertebrae are: (1) the bodies are relatively small, oval in shape and broadest from side to side; (2) the neural arches are large; (3) the transverse

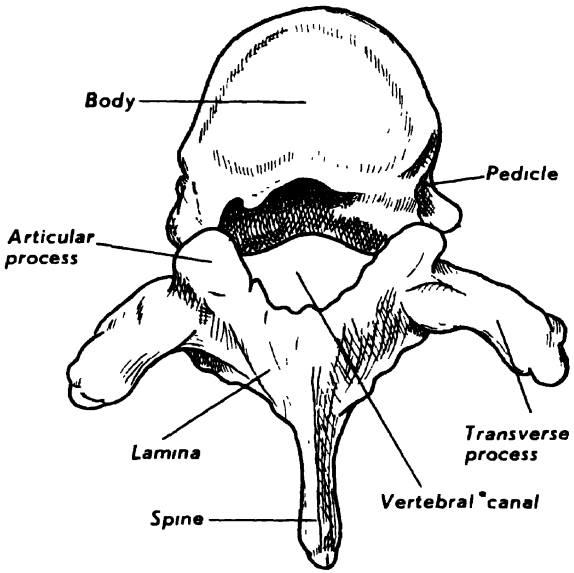


Fig. 7.2 A thoracic vertebra — superior aspect.

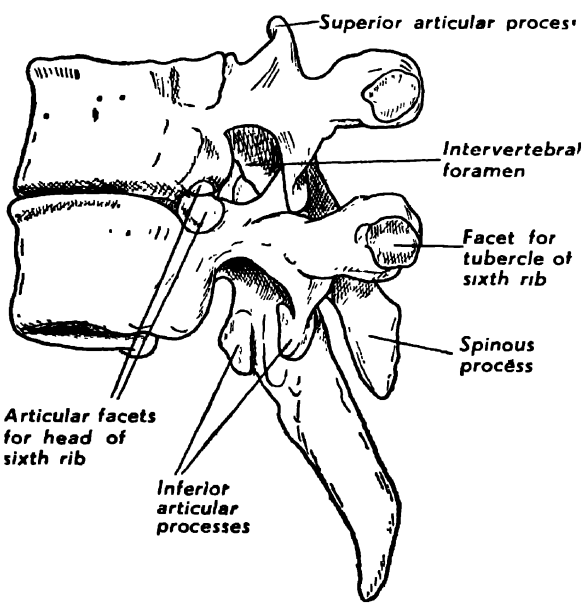


Fig. 7.3 Articulated thoracic vertebrae — lateral aspect.

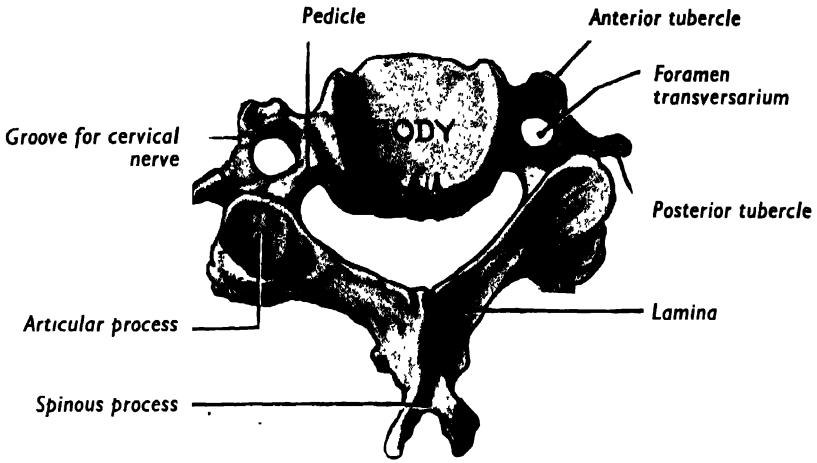


Fig. 7.4 A typical cervical vertebra.

processes are perforated from above downwards by a foramen (the *foramen transversarium*) through which the vertebral artery runs on its way to enter the skull; (4) the spinous processes of the first six vertebrae are bifid (divided) at the tips but that of the seventh is not so divided, it is the most prominent cervical spinous process and, as it produces a visible prominence on the back of the neck, the seventh cervical vertebra is called the *vertebra prominens*.

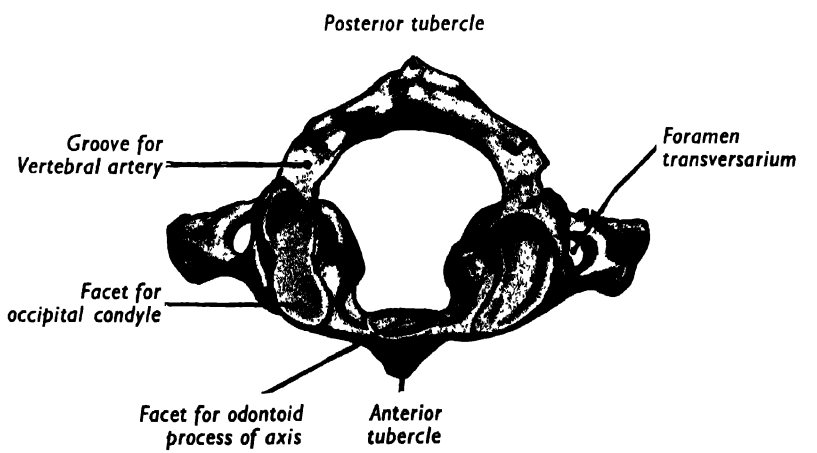


Fig. 7.5 The atlas — superior aspect.

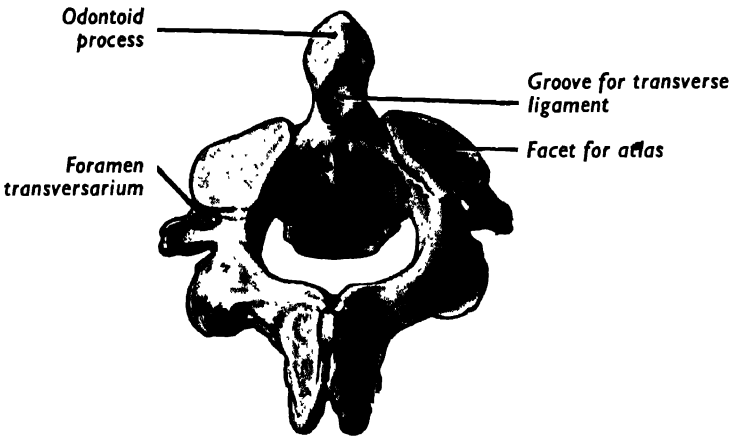


Fig. 7.6 The axis – posterosuperior aspect.

THE THORACIC VERTEBRAE

The twelve thoracic vertebrae increase in size from above downwards and show the following characteristics: (1) the bodies are heart-shaped and on either side they bear facets for articulation with the heads of the ribs; (2) the neural arches are relatively small; (3) the spinous processes are long and downwardly directed; (4) the transverse processes are conspicuous and articulate (in the case of the upper ten) with tubercles on the ribs (see Figs. 7.2, 7.3).

THE LUMBAR VERTEBRAE

The five lumbar vertebrae show the following features: (1) the bodies are large and wide; (2) the vertebral foramina are triangular

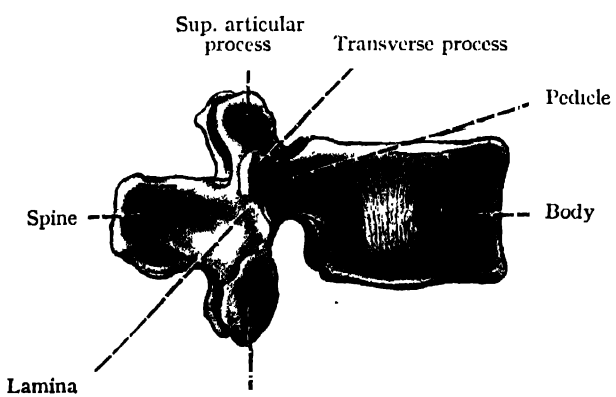


Fig. 7.7. A typical lumbar vertebra — lateral aspect.

in shape and are larger than in the thoracic region; (3) the spines are quadrangular and project directly backwards; (4) the superior articular processes have projecting backwards from them the mamillary processes.

The lumbar vertebrae, of course, have no facets for articulation with the ribs.

THE SACRUM

The sacrum is triangular in shape and consists of five vertebrae fused into one bone. Its apex is directed downwards and articulates with the coccyx; its base, directed upwards, articulates with the lumbar spine at the lumbosacral junction. The pelvic surface is directed forwards and is perforated by the anterior sacral foramina, the dorsal surface is directed backwards and is perforated by the

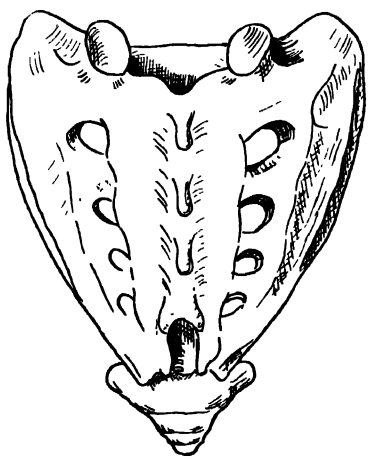


Fig. 7.8 The sacrum and coccyx · posterior aspect.

posterior sacral foramina. The sacral nerves pass through these foramina as they leave the spinal canal. The lateral surface bears in its upper part an articular surface which articulates with the ilium at the sacro-iliac joint. The vertebral arches of the sacral vertebrae are fused into one sacral canal and the anterior and posterior sacral foramina communicate with the canal.

THE COCCYX

The coccyx is a small triangular bone composed of four rudimentary vertebrae; the lower three are usually fused together and the

first piece is generally separate. The apex of the coccyx points downwards and forwards and the base articulates with the sacrum.

THE SPINAL CURVES

When viewed from in front or behind the spine is straight but when seen from the side it presents a series of curves. In the foetus there is one *primary curve* with its convexity backwardly directed from the cervical to the sacral region. When the child can sit upright a *secondary curve*, convex forwards, develops in the cervical region and when he can stand a similar curve develops in the lumbar region.

The adult vertebral column shows (see Fig. 7.1) forward convexity of the cervical and lumbar regions and backward convexity of the thoracic and sacral regions.

JOINTS OF THE VERTEBRAL COLUMN

The majority of the vertebrae articulate with each other through cartilaginous joints, the *intervertebral discs*, between their bodies and

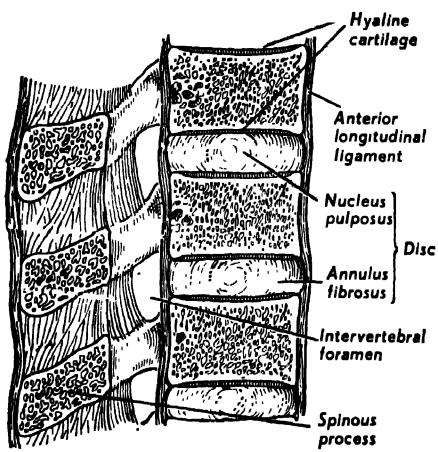


Fig. 7.9 Sagittal section of part of the vertebral column showing ligaments and intervertebral discs.

by a series of synovial joints between the articular facets on the vertebral arches. The vertebral bodies are joined also by the *anterior and posterior longitudinal ligaments* which run as continuous bands down their anterior and posterior surfaces.

The intervertebral disc. Each disc consists of an upper and a lower

cartilaginous plate between which lies the jelly-like *nucleus pulposus* which is itself surrounded by a fibrous ring called the *annulus fibrosus*. No discs are found between the first two cervical vertebrae nor, of course, in the sacrum or coccyx.

The neurocentral joints. In the cervical region there are small synovial joints in the margins of the intervertebral discs adjoining the intervertebral foramina; these are called the *neurocentral joints*. Degenerative changes in these joints, a condition known as *cervical spondylosis*, may be responsible for local and referred pain because the spinal nerve, as it passes through the intervertebral foramen, may be damaged by osteophytes (small bony spurs which form at the periphery of osteoarthritic joints).

The *synovial joints* between the vertebral arches consist of the articulations between the superior and inferior articular facets of the adjacent vertebrae. These facets are covered with hyaline cartilage and the joints possess capsular ligaments and synovial membranes.

The neural arches are also connected by the *flaval ligaments* (*ligamenta flava*) which join the laminae, the *interspinous ligaments* between the spinous processes and the *supraspinous ligaments* which run down the tips of the spinous processes. In the cervical region the supraspinous ligament is greatly strengthened to become the *nuchal ligament* (*ligamentum nuchae*) which extends from the seventh cervical vertebra to the occiput.

The movements which occur in the vertebral column are *flexion*, *extension*, *lateral flexion*, *circumduction* and *rotation*. Flexion is forward movement, extension is backward movement and lateral flexion is the bending of the body to one or other side. Circumduction is a combination of these and rotation occurs when the back is twisted; the latter is most free in the thoracic part of the vertebral column and absent in the lumbar.

THE ATLANTO-OCCIPITAL JOINT

This synovial joint intervenes between the occipital condyles which are found on either side of the foramen magnum above, and the facets on the superior surfaces of the lateral masses of the atlas vertebra below. The principal movements are *flexion* and *extension*, as in nodding the head, but a limited degree of *lateral flexion* of the head also occurs.

THE ATLANTO-AXIAL JOINT

The synovial joint between the first and second cervical vertebrae

consists of three parts, one between the odontoid process and the anterior arch of the atlas and the other two between the two lateral masses of the bones. The movement occurring between the bones is rotation of the atlas (and hence the head) on the axis.

RADIOGRAPHIC APPEARANCES OF THE VERTEBRAL COLUMN

Cervical Region

A posterior view through the open mouth shows the atlanto-axial articulation with the odontoid process lying between the two lateral masses of the atlas vertebra.

The lateral projection shows the anterior and posterior arches of the atlas, the odontoid process projecting upwards from the body of the axis, the posterior intervertebral articulations and the spinous processes. The transverse processes are superimposed on the bodies in this projection. The anterior and posterior surfaces of the vertebral bodies and the posterior surface of the spinal canal form smooth and roughly parallel curves.

Thoracic Region

The posterior radiograph shows the bodies of the vertebrae, with the spinous processes and laminae superimposed upon them. Each spinous process is projected on to the vertebra below. The transverse processes project laterally and those of the first thoracic vertebra are also directed upwards, in contrast to those of the cervical transverse processes which are directed somewhat downwards. The intervertebral disc spaces are seen with varying degrees of clarity depending on their relation to the axis of the X-ray beam. The pedicles produce a characteristic line of white oval rings superimposed on each side of the vertebral bodies. The costovertebral and the costotransverse joints will be seen. The transradiant trachea and the dense heart shadow will also be projected on to the film.

In the lateral projection the bodies, rectangular in shape, are seen to be separated by the intervertebral disc spaces; the pedicles project posteriorly from the bodies and between them the intervertebral foramina are seen. The ribs, spinous processes and laminae tend to be superimposed and the upper four thoracic vertebrae are usually greatly obscured by the shoulder girdles.

Lumbar Region

The posterior view shows the bodies, laminae, spinous processes, transverse processes and intervertebral disc spaces clearly. The

pedicles produce conspicuous ring-shaped shadows and just above these the posterior intervertebral joints are seen as narrow slits.

The lateral view demonstrates clearly the bodies, the disc spaces,

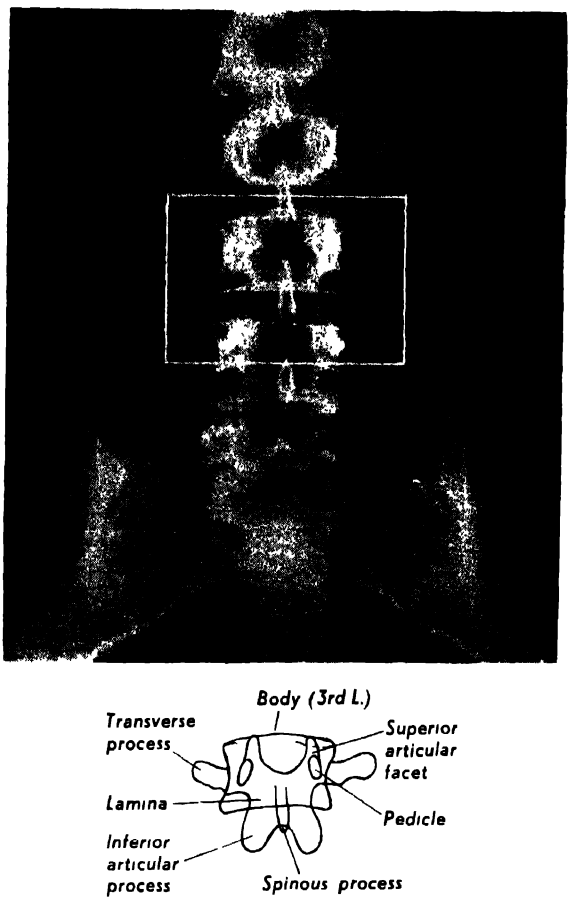


Fig. 7.10 (*a*) Radiographic appearances of the lumbosacral region — posteriorprojection; (*b*) Line drawing of 3rd lumbar vertebra.

the intervertebral foramina, the intervertebral joints and the spinous processes.

Oblique views of the lumbosacral junction are sometimes required for the demonstration of the part of the neural arch between the superior and inferior articular processes.

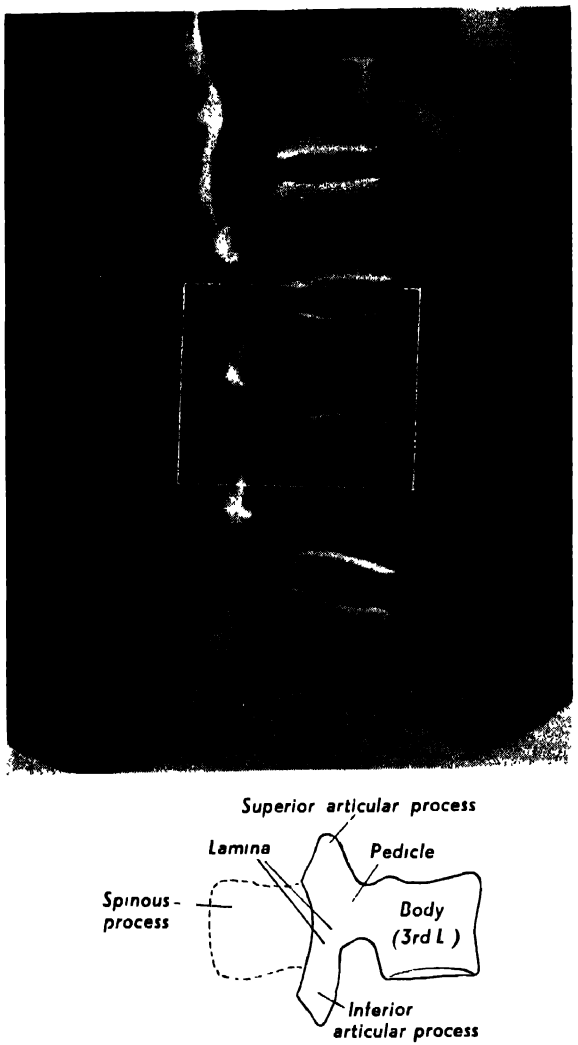


Fig. 7.11 (*a*) Radiographic appearances of the lumbar spine – lateral projection; (*b*) Line drawing of 3rd lumbar vertebra.

Sacrum and Coccyx

The sacrum is seen as a triangular bone with the apex below. It is made up of two lateral portions or masses and a body between them. The body is relatively dense as it consists of the fused bodies and

neural arches of the sacral vertebrae. Articulating with the lower end is the coccyx which also is shaped like an inverted triangle.

Ossification of the Vertebral Column

Each vertebra ossifies from three primary centres, one for the body and one for each side of the neural arch. At birth a radiograph will show these separate centres but by the end of the 1st year the neural arches will have fused and by 6 years of age the arches will be joined with the bodies. Failure of closure of the neural arch sometimes occurs especially in the lumbar region, and it is then called spina bifida. During childhood secondary ossific centres appear for the tips of the spinous and transverse processes and a ring-shaped epiphysis appears for the upper and lower surfaces of each vertebral body. The centre of this ring remains unossified and persists as the cartilaginous plate which is found in the upper and lower surfaces of the intervertebral discs.

THE THORACIC CAGE

The thoracic cage is a conical structure composed principally of bones and muscles. The bones consist of the twelve thoracic vertebrae posteriorly, the sternum anteriorly and the encircling ribs (p. 62, 70). Between the ribs are the intercostal muscles and separating the thorax from the abdomen is the diaphragm. The apex of each half of the thoracic cavity is separated from the neck by a fascial layer called Sibson's fascia. The thoracic cage is lined by pleura (p. 152) and contains the lungs and mediastinum.

The surface markings of the thorax are dealt with on page 267 *et sqq.*

THE STERNUM

The sternum forms the middle portion of the anterior wall of the thorax and consists of three parts, the *manubrium*, the *body* and the *xiphoid* process. In early life these parts are represented by circular centres of ossification which are sometimes visible in slightly oblique anterior and posterior radiographs.

The *manubrium* is a triangular bone which articulates with the clavicles on either side of its upper border and between the articular surfaces is the *suprasternal notch.* Below, the manubrium articulates with the body of the sternum at the *sternal angle.* The second costal cartilages lie at this level. The first costal cartilages articulate with the lateral aspects of the manubrium just below the clavicles.

The *body* of the sternum is long and narrow and articulates in conjunction with the manubrium with the second costal cartilages. Below these it articulates with the third, fourth, fifth, sixth and seventh costal cartilages on each side.

The *xiphoid process* is the smallest and lowest piece of the sternum; it may be cartilaginous or bony.

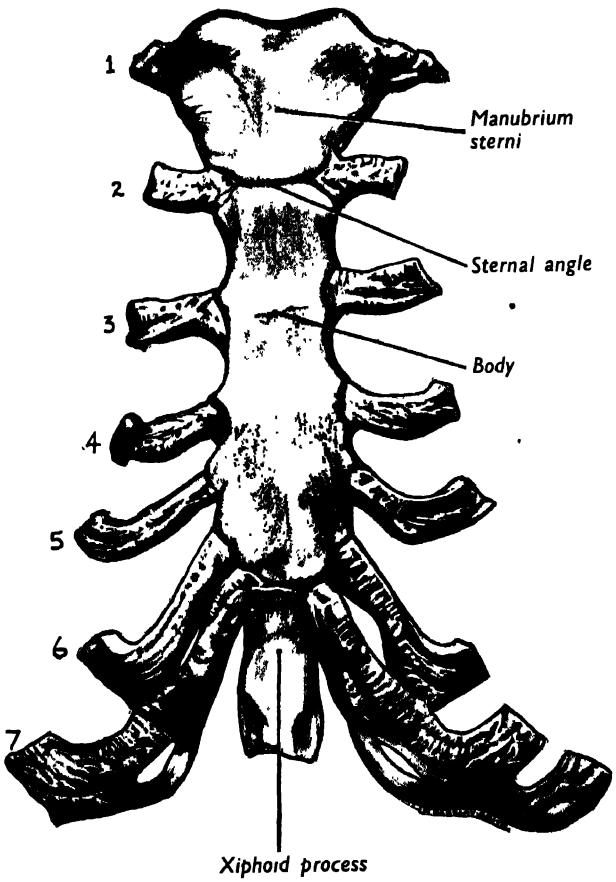


Fig. 7.12 The sternum and costal cartilages. The numbers are the serial numbers of the costal cartilages.

THE RIBS

There are usually twelve ribs on each side. All articulate posteriorly with the vertebral column and arch obliquely round the thorax to be connected, in the case of the upper seven ribs, through

the *costal cartilages* to the sternum. The eighth, ninth and tenth have cartilages which are attached to each other and join the seventh costal cartilage. The eleventh and twelfth ribs are called floating ribs since their anterior ends are free.

The anterior end of each rib is expanded and the posterior end possesses a *head*, a *neck* and a *tubercle*; these will be considered in connection with the *costovertebral joints*. Between the ribs are the *intercostal spaces* which are occupied by the intercostal muscles, nerves and blood vessels.

Sometimes *cervical ribs* are met with. They arise from the seventh cervical vertebra and may join the first thoracic rib, the first costal

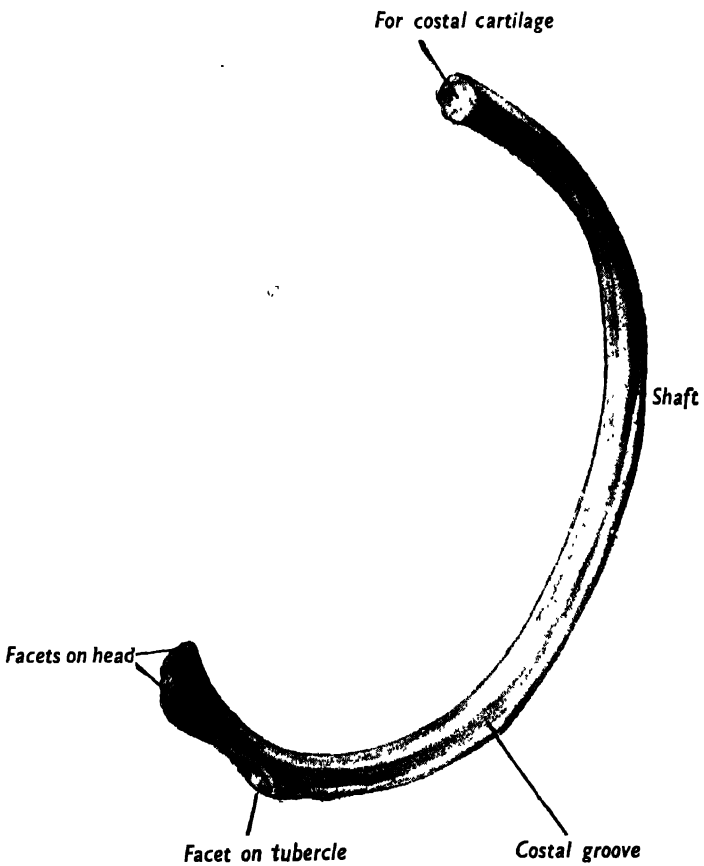


Fig. 7.13 A typical rib of the left side — inferior aspect.

cartilage or the sternum. They are of importance as they may cause nervous and vascular symptoms in the upper limbs.

JOINTS OF THE THORAX

THE MANUBRIOSTERNAL JOINT

The articulation between the manubrium and the body of the sternum is a cartilaginous joint so the two bones are connected by a plate of fibrocartilage. There is a restricted degree of movement at the joint during breathing.

THE STERNOCOSTAL ARTICULATIONS

Synovial joints exist between the body of the sternum and the second to the seventh costal cartilages of each side.

THE COSTOVERTEBRAL JOINTS

Each rib articulates with the vertebral column by two synovial joints, one between the head of the rib and the facet on the side of the appropriate thoracic vertebra and the other between the tubercle and neck of the rib and the transverse process of the vertebra. Elevation of the ribs occurs at these joints during breathing, thus helping to draw air into the lungs.

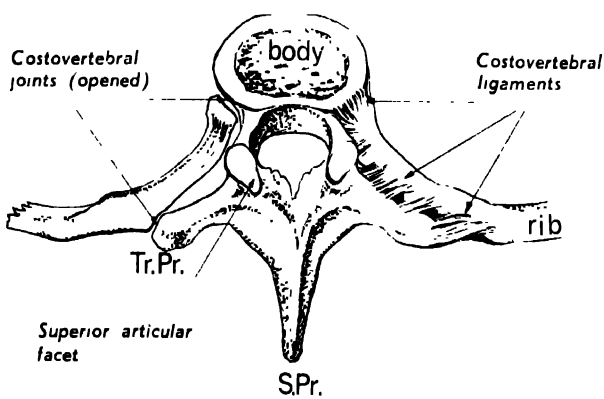


Fig. 7.14 Diagram to show, from above, the costovertebral articulations. On the left side the costovertebral ligaments and joint capsules have been removed.

Pathological considerations

The vertebral column may show abnormal curves for a variety of

reasons and these are termed: *kyphosis*, a posterior convexity ('round shoulders'), *lordosis* is the opposite, an exaggerated anterior convexity (as normally occurs in late pregnancy), *scoliosis* is a lateral curvature (e.g. following infantile paralysis or, more commonly, of unknown causation 'idiopathic scoliosis').

A crippling condition known as *ankylosing spondylitis* results in fusion of the vertebral and sacro-iliac joints. This disease is sometimes grouped as one of the rheumatoid diseases.

Spondylolisthesis is the term used to describe the forward slipping of a vertebra (usually of the lower lumbar region) on the vertebra below as a result of a defect in the neural arch.

Slipped or prolapsed intervertebral disc is a common cause of backache, sciatica, etc. It results from a rupture of the annulus fibrosus of the disc, usually by a forcible flexion movement (e.g. lifting a weight) so that the semi-fluid nucleus pulposus is extruded posteriorly or posterolaterally. The extruded nucleus may compress the spinal cord or a nerve root.

Vertebrae are frequently the site of metastatic cancer.

Radiography of the vertebral bodies provides a useful way of studying bone changes in various developmental abnormalities and metabolic disturbances.

8

The Bones and Joints of the Appendicular Skeleton

BONES AND JOINTS OF THE UPPER LIMB

THE CLAVICLE

The clavicle or collar bone runs horizontally at the root of the neck and transmits part of the weight of the upper limb to the trunk. The shaft is *S*-shaped and its medial half is convex forwards. The medial end is roughly square and articulates with the sternum,

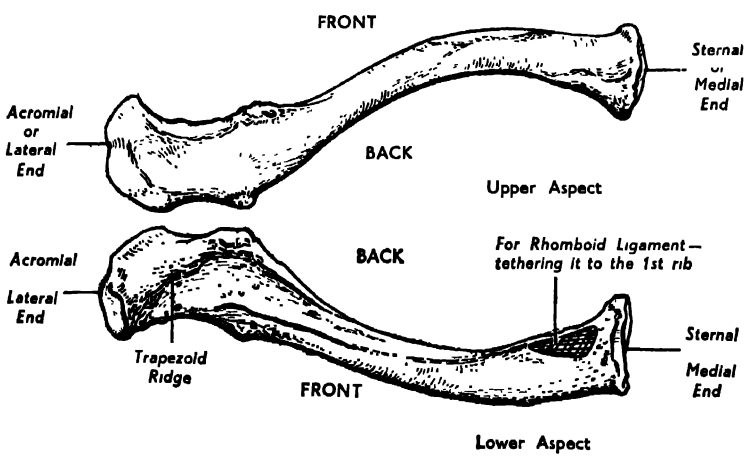


Fig. 8.1 The left clavicle.

the lateral end is flattened and articulates with the acromion of the scapula. The lateral quarter of the bone shows on its inferior surface a prominent tubercle known as the *conoid tubercle* for attachment of the conoid ligament and lateral to this is the *trapezoid ridge*, to which the trapezoid ligament is attached. These two ligaments which together are known as the *coracoclavicular ligament* connect the

clavicle with the coracoid process of the scapula. The under surface of the inner part of the bone shows a deep impression, the *rhomboid fossa* which is often visible on radiographs and is the site of attachment of the costoclavicular ligament which unites the clavicle to the first rib.

THE SCAPULA

The scapula is a large flattened triangular bone lying on the posterolateral aspect of the chest and extending from the second to the seventh ribs. The *body* possesses a concave anterior surface, the *subscapular fossa*, a posterior surface from which the *spine of the scapula* projects, a *vertebral border* medially and an *axillary border* laterally. The *superior border* and the vertebral border meet at the *superior angle* and the vertebral and axillary borders meet at the *inferior angle*. There is a flattened *lateral angle* between the axillary and superior borders which bears the *glenoid cavity* for articulation with the head of the humerus. The part of the scapula bearing the glenoid cavity is called the *head* and it is separated by a constriction called the *neck* from the rest of the bone. Projecting from the anterior surface of the head is the *coracoid process*. The spine of the scapula divides the posterior surface into the *supraspinous* and *infraspinous fossae*. The lateral end of the spine is expanded and flattened to form the *acromion*, with which the clavicle articulates.

THE HUMERUS

The humerus is the longest of the bones in the upper limb; it has an almost cylindrical shaft with a rounded, medially directed head and an expanded lower end.

The *upper end* consists, in addition to the head, of the *lesser tuberosity* anteriorly and the *greater tuberosity*, the most lateral bony point in the shoulder region. Separating the two tuberosities is the *bicipital groove*. Immediately adjoining the margin of the head is the *anatomical neck* but the *surgical neck* is that part of the shaft which comes immediately below the head and tuberosities.

The *shaft* has a roughened elevation, the *deltoid tuberosity*, in the middle of its lateral surface into which the deltoid muscle is inserted. Below this, passing obliquely downwards and forwards is the *spiral groove* for the radial nerve.

The *lower end* of the humerus is expanded transversely and shows two prominences above the articular portion, the *medial* and *lateral epicondyles*, from which the *supracondylar ridges* extend proximally.

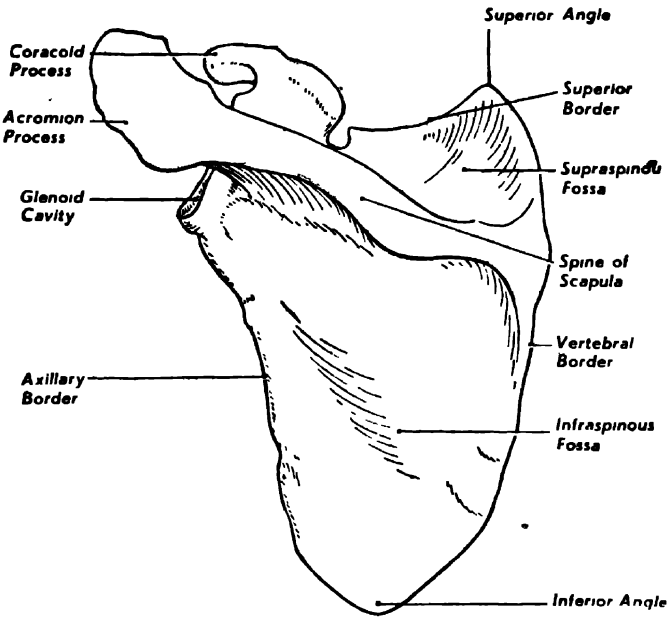


Fig. 8.2 The left scapula - posterior surface.

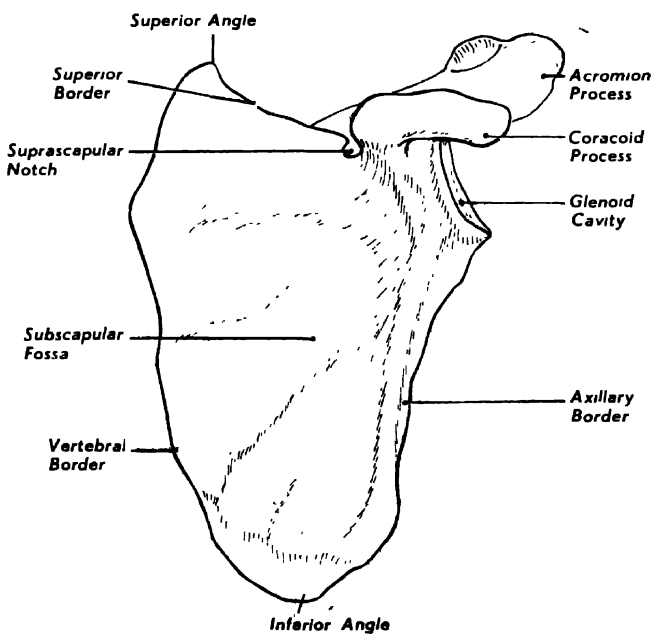


Fig. 8.3 The left scapula — anterior surface.

The lateral portion of the articular surface, the *capitulum*, is rounded and articulates with the radial head; the medial part, which is called the *trochlea*, is deeply grooved and articulates with the ulna. A deep hollow, the *olecranon fossa*, is seen immediately above the trochlea and it accommodates the olecranon when the elbow is extended. On the anterior surface of the bone opposite the olecranon fossa is the *coronoid fossa* which receives the coronoid process when the elbow is fully flexed.

It will be observed that the medial part of the lower end of the humerus extends more distally than the lateral so that the axis of the elbow joint does not make a right angle with the long axis of the

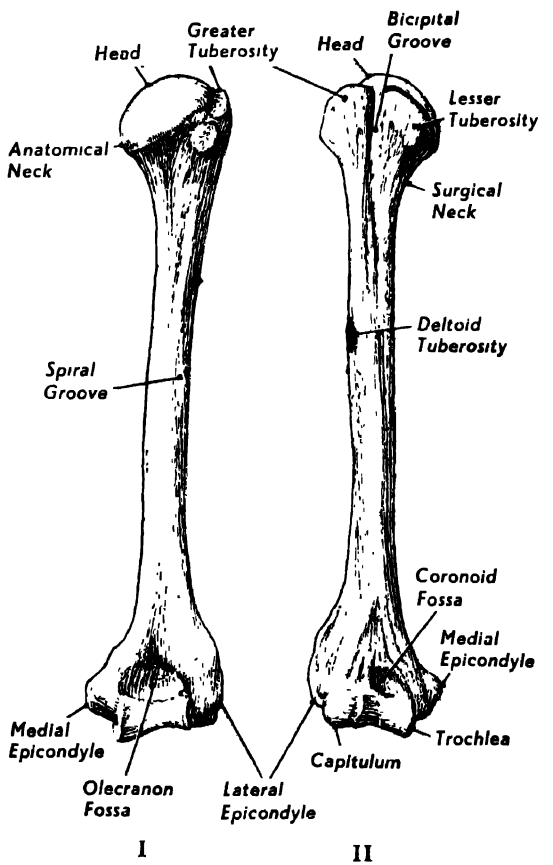


Fig. 8.4 Posterior (I) and anterior (II) surfaces of the right humerus.

humerus. Thus the forearm and arm are not in the same straight line when the elbow is extended but make an angle of about 164° with each other; this is called the *carrying angle* and it enables objects carried by hand with the arm outstretched to be more easily swung clear of the thighs.

THE RADIUS

The radius is the lateral of the two forearm bones and has a cylindrical *head* proximally and an expanded *lower end* from which the *styloid process* projects distally; this end of the bone is grooved on its posterior surface where the extensor tendons of the wrist and fingers pass across it. The *neck* comes immediately distal to the head

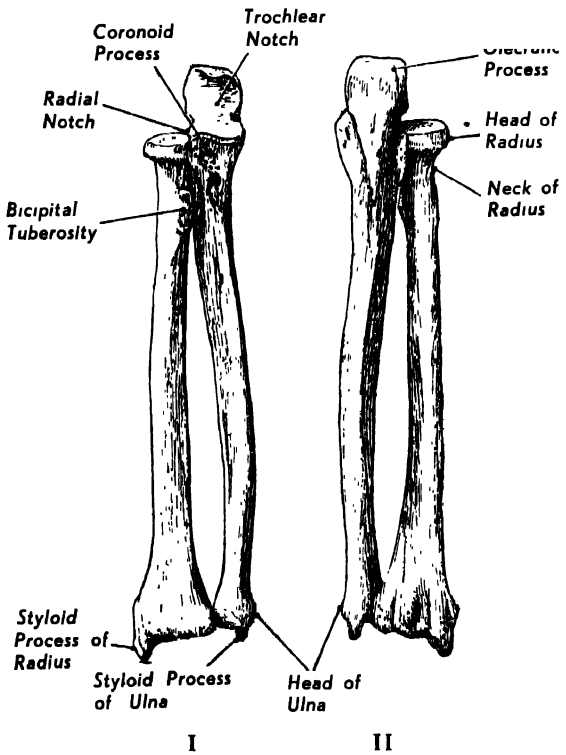


Fig. 8.5 Anterior (I) and posterior (II) surfaces of the radius and ulna.

and below this projecting laterally is the *radial or bicipital tuberosity* into which is inserted the tendon of the biceps muscle. The *shaft*

has a prominent interosseous border from which the interosseous membrane (see p. 87) stretches across to the ulna.

THE ULNA

The ulna is longer than the radius and lies medial to it. At its *upper end* are two conspicuous processes, the *coronoid process* and the *olecranon* and between these is the deep *trochlear notch* with which the trochlea of the humerus articulates. On the lateral side of the coronoid process is the *radial notch* for articulation with the head of the radius at the superior radio-ulnar joint. The *lower end* is small and shows the rounded *head* separated by a shallow groove from the *styloid process* which projects distally from the posteromedial aspect of this part of the ulna. The *shaft* separates the upper from the lower end and is united to the radial shaft by the interosseous membrane.

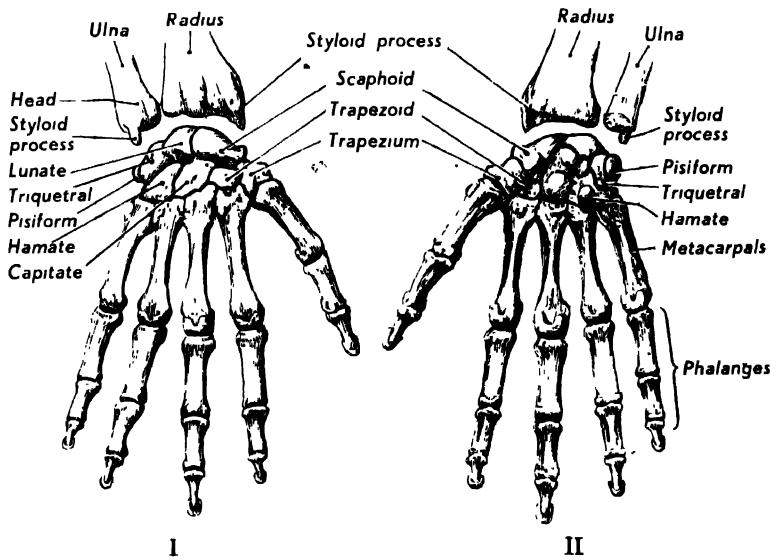


Fig. 8.6 Posterior or dorsal (I) and anterior or palmar (II) surfaces of the right wrist and hand.

THE HAND

The bones of the hand are divided into (1) the carpal or wrist bones; (2) the metacarpal bones; and (3) the phalanges or bones of the digits.

THE CARPAL BONES

The carpus consists of eight bones arranged in two rows, a proximal and a distal. From the lateral side the proximal row contains the *scaphoid*, the *lunate*, the *triquetrum* and the *pisiform*. The distal row in the same order consists of the *trapezium*, the *trapezoid*, the *capitate* and the *hamate*. The pisiform is set somewhat anterior to the triquetral, the hamate is characterized by a prominent process directed anteriorly and the capitate is the largest bone in the carpus. The scaphoid is frequently the site of fracture and its radiographic demonstration is helped by the movement of *ulnar deviation* which is described under movements of the wrist joint.

THE METACARPAL BONES

There are five metacarpal bones, each of which possesses a *head* distally, a *shaft* and, proximally, a *base*. The first metacarpal articulates with the thumb and is set on a more anterior plane than the remaining four.

THE PHALANGES

These short long-bones also have a shaft and two extremities; the shafts taper distally. There are three phalanges for each finger and two for the thumb.

JOINTS OF THE UPPER LIMB

THE STERNOCLAVICULAR JOINT

This is a synovial joint between the medial end of the clavicle and the facet on the lateral aspect of the upper border of the manubrium of the sternum.

THE ACROMIOCLAVICULAR JOINT

This synovial joint intervenes between the lateral end of the clavicle and the facet on the medial margin of the acromion of the scapula. A number of important ligaments strengthen this joint one of which, the *coracoclavicular ligament* (p. 74), unites the coracoid process to the under surface of the lateral part of the clavicle.

THE SHOULDER JOINT

This is a synovial joint of the ball-and-socket type. The hemispherical head of the humerus articulates with the shallow glenoid

cavity of the scapula which is deepened by a fibrocartilaginous ring, the *glenoid labrum*, attached round its margin. Hyaline cartilage covers the articulating surfaces and a capsule, lax to permit a wide range of movement, encloses the joint. The capsule is strengthened by ligaments and muscles and some of the tendons of the latter, e.g. that of supraspinatus, actually blend with it. The synovial membrane lines the capsule and also covers the tendon of the long head of the biceps muscle (see p. 113) which runs through the joint.

The shoulder joint has a wide range of movement: *flexion* is forward and medial movement of the arm; *extension* is backward and lateral movement of the arm; *abduction* is raising the arm sideways and, in combination with scapular movement, raising it above the head and *adduction* is movement of the arm towards or across the chest. *Circumduction* is a combination in sequence of these movements (as in skipping) and the remaining movements are *external* and *internal* rotation.

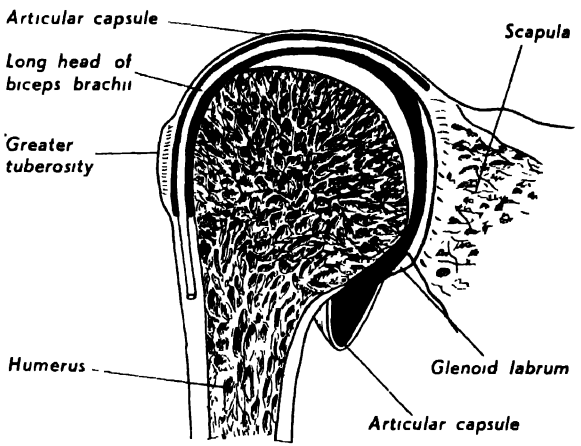


Fig. 8.7 Longitudinal section through the right shoulder joint.

RADIOGRAPHIC APPEARANCES OF THE SHOULDER REGION

The posterior and inferosuperior projections will be described.

The posterior radiograph shows the outer two-thirds of the clavicle, the scapula and the upper one-third of the humerus, the acromioclavicular and shoulder joints and the upper ribs and part of the lung.

The clavicle is seen at the upper part of the radiograph and is



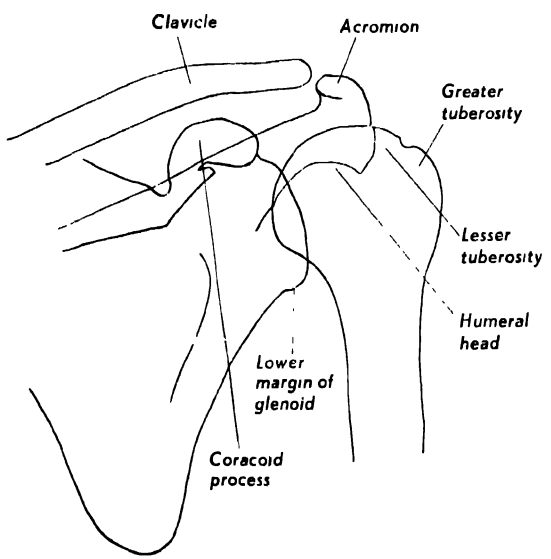


Fig. 8.8 (*a*) Radiograph of the left shoulder region. Posterior projection. (*b*) Line drawing of (*a*).

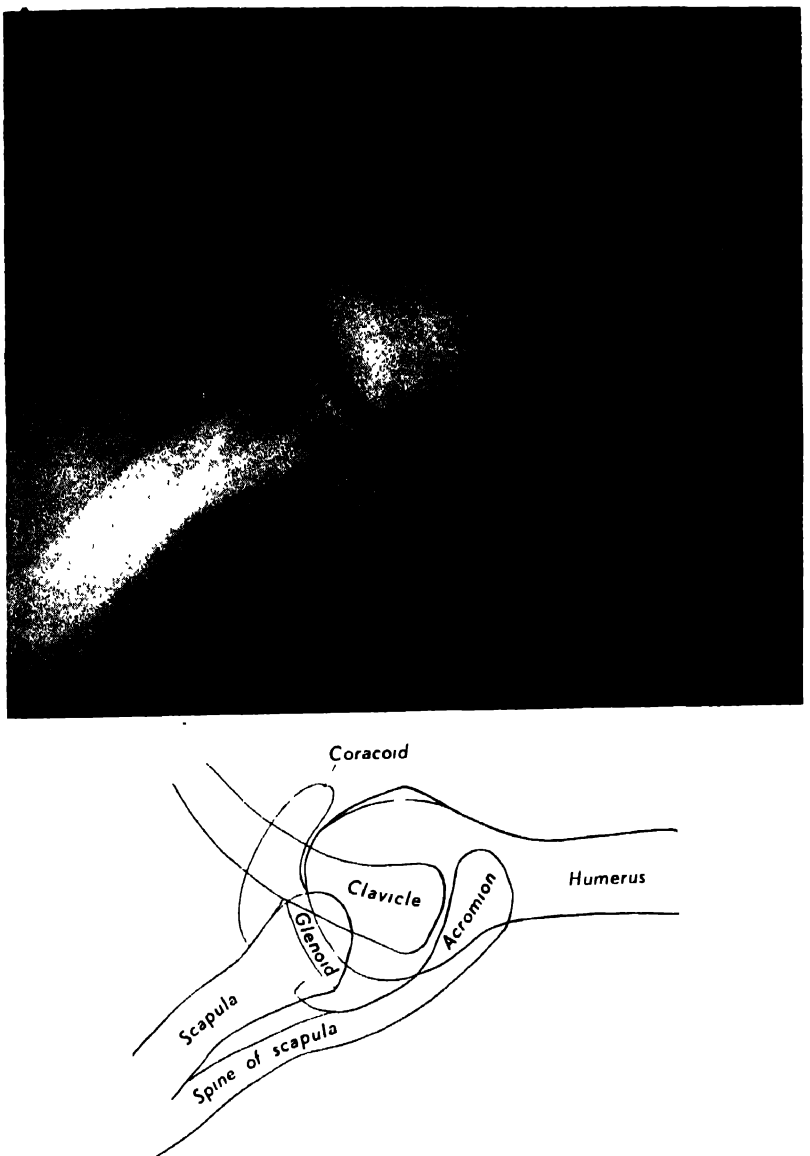


Fig. 8.9 (*a*) Radiograph of shoulder joint. Vertical or superior projection. (*b*) Line drawing of (*a*).

separated from the acromion by a gap which represents the acromioclavicular joint. The acromion, seen at the lateral end of the spine of the scapula, intervenes in the radiograph between the humeral head and the clavicle. The glenoid is shown as an oval shadow and it may be overlapped to a variable extent by the humeral head. The coracoid process is seen projecting upwards from the head of the scapula; it may be superimposed on the glenoid cavity and its appearance varies considerably according to the position of the shoulder at the time of the examination. The outlines of the superior, axillary and vertebral borders of the scapula and its superior and inferior angles are also shown.

The smooth rounded humeral head projects upwards and medially and the greater tuberosity is clearly shown on the lateral side but the lesser tuberosity and the bicipital groove are superimposed upon the bone and will not be recognized. The deltoid tuberosity produces a slightly raised and roughened area on the lateral aspect of the middle of the shaft.

The inferosuperior projection may be taken in various ways; in cases of injury when abduction may be painful or impossible the cone of the X-ray tube may be inserted between the elbow and the flank, the cassette being held on top of the shoulder by the hand of the uninjured side. The interpretation of this radiograph is facilitated by first identifying the front; this is done by recognizing the forwardly projecting coracoid process. It is then easy to proceed to the identification of the clavicle, the acromion and the spine of the scapula. The humeral head and glenoid cavity are seen and the axillary border of the bone is projected as a shadow running posteromedially from the glenoid cavity behind the clavicle with which it is sometimes confused.

Ossification of the Shoulder Region

The upper end of the humerus is ossified from three centres, one which appears during the first year for the head, one for the greater tuberosity which appears during the third year and one for the lesser tuberosity which appears during the fifth year. These fuse into one centre during the sixth year and the single large epiphysis thus formed is separated from the shaft by the epiphyseal cartilage plate which will be projected as two transradiant lines on the radiograph if the X-ray beam strikes it obliquely. This appearance is sometimes mistaken for a fracture but careful study will show that thin white lines of cortical bone form the margins of the transradiant areas and these would not be seen in fractures. Secondary ossific centres for the acromion and tip of the coracoid process may be seen during adolescence.

THE ELBOW JOINT

This consists of two joints, the *humero-ulnar* between the trochlea of the humerus and the trochlear notch of the ulna, and the *humero-radial* between the capitulum and the radial head. These constitute a hinge joint and as with all such joints the medial and lateral ligaments are strong but the capsule is thin anteriorly and posteriorly. The synovial membrane is extensive, it lines the capsule and the coronoid and olecranon fossae and is continuous with the synovial membrane of the superior radio-ulnar joint.

The movements of the joint are *flexion*, i.e. approximation of the anterior surfaces of the arm and forearm, and *extension*, i.e. straightening the elbow.

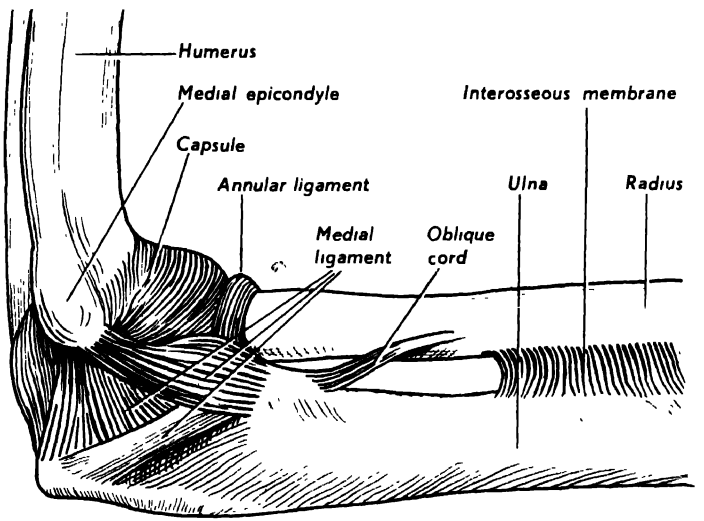


Fig. 8.10 The left elbow and superior radio-ulnar joints - medial aspect.

THE PROXIMAL RADIO-ULNAR JOINT

This synovial joint of the pivot type is situated between the circumference of the radial head and a ring made up of the *annular ligament* and the radial notch of the ulna. The synovial membrane is continuous with that of the elbow joint. The movements will be considered when the inferior radio-ulnar joint is described.

RADIOGRAPHIC APPEARANCES OF THE ELBOW REGION

The posterior and lateral projections will be described. In the former the elbow is extended and in the latter it is flexed to a right angle.

The posterior projection includes the lower end of the humerus, the proximal ends of the radius and ulna and the elbow and superior radio-ulnar joints. On the inner side of the lower end of the humerus the medial epicondyle is conspicuous and the shadow of the olecranon is superimposed on the trochlea, above which the olecranon and coronoid fossae produce a triangular transradiancy. The articular cartilage of the elbow joint produces a parallel translucent space between the rounded capitulum and the radial head and between the trochlea and coronoid process. The neck and bicipital

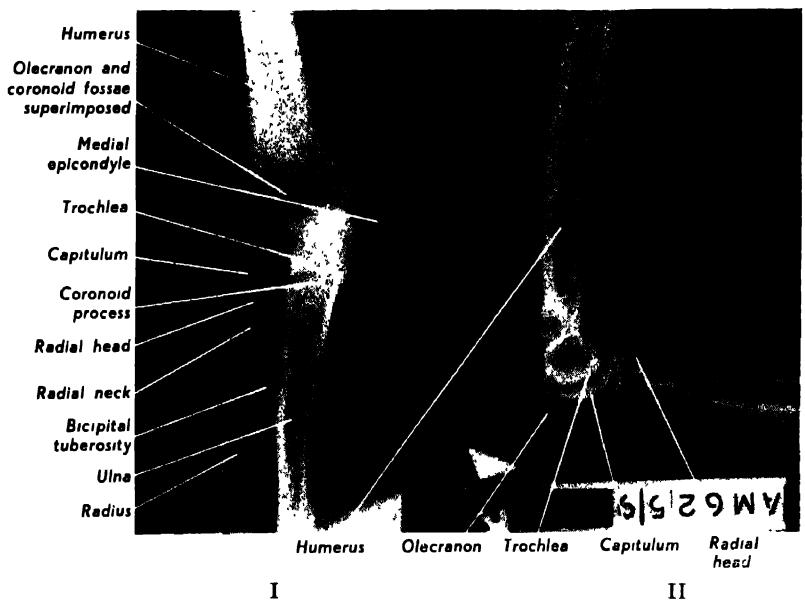


Fig. 8.11 Radiograph of the right elbow joint. Posterior (I) and medial (II) projections.

tuberosity of the radius and the superior radio-ulnar joint are also seen.

The lateral projection of the elbow shows the epicondyles superimposed to a variable extent. The capitulum and trochlea are also superimposed and present similar curved outlines. The capitulum can be recognized as it will lie parallel to the articular surface of the radial head, and it projects for about one-third of its thickness in front of the anterior surface of the humeral shaft. It will help in the identification of the capitulum if it is remembered that in the normal elbow joint prolongation proximally of the long axis of the

radius will always lead to the capitulum whatever the position of the elbow joint.

Ossification of the Elbow Region

Up to the age of about 2 years there are no epiphyseal centres visible in the elbow region so that a wide gap appears to separate the humerus from the forearm bones in the radiograph. The first centre to appear is that for the capitulum at 2½ years, then at about 5 years the medial epicondyle and the radial head are visible. Next to appear are the centres for the trochlea and tip of the olecranon at 10 years, followed at 12 years by the external epicondyle.

THE MIDDLE RADIO-ULNAR JOINT

This consists of the *interosseous membrane* which connects the radius to the ulna and extends for the greater part of the length of the shafts of these bones.

THE DISTAL RADIO-ULNAR JOINT

This is a synovial joint between the head of the ulna and the ulnar notch on the medial side of the lower end of the radius. An articular disc, the *triangular cartilage*, extends from the styloid process of the ulna to the radius and the two bones are also united by the articular capsule.

The movements of the proximal, middle and distal radio-ulnar joints are pronation and supination. *Pronation* is rotation of the radius round the ulna so that the palm of the hand faces backwards when the arm is hanging by the side. *Supination* is rotation of the radius round the ulna so that the palm of the hand faces forwards when the arm is hanging by the side.

THE WRIST JOINT

The wrist or radiocarpal joint is a synovial joint between the distal surface of the radius and the triangular cartilage of the distal radio-ulnar joint above, and the proximal articular surfaces of the navicular, lunate and triquetral bones below. It will thus be seen that the lower end of the ulna does not articulate with the carpal bones and does not form part of the wrist joint.

The movements occurring at this joint are *flexion*, i.e. forward movement of the hand; *extension*, i.e. backward movement of the hand, *abduction* and *adduction*, radial and ulnar deviation respectively,

and *circumduction* which is a combination in sequence of these movements. Radiographs of the wrist are often taken in ulnar deviation as the scaphoid is more adequately demonstrated in this position.

The *carpal tunnel* is a groove on the anterior (palmar) aspect of the carpal bones bridged over by the transverse carpal ligament. In the tunnel so formed run the tendons of the flexor muscles and the median nerve. It is sometimes necessary to demonstrate the bony part of the tunnel by an axial radiographic projection when searching for a cause of pain in the wrist and hand.

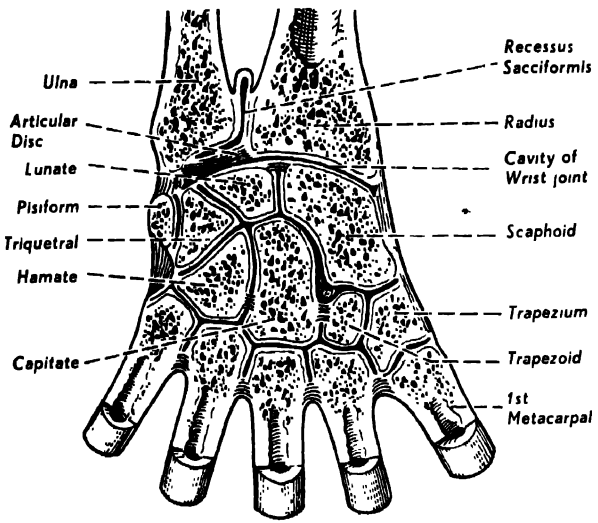


Fig. 8.12 Section showing wrist, carpal and carpometacarpal joints.

RADIOGRAPHIC APPEARANCES OF THE WRIST AND HAND

The anterior radiograph of the wrist includes the lower ends of the radius and ulna, the inferior radio-ulnar joint, the carpal and the proximal ends of the metacarpal bones. The carpal bones are seen to be separated by the 'spaces' of the intercarpal joints and in the proximal row of these bones the pisiform is seen to be superimposed on the triquetrum. In the distal row of the carpus the hamate shows an oval white ring caused by its hook. The wrist joint is seen intervening between the radius and the scaphoid and lunate; the radial styloid process is observed to extend more distally than that of the ulna and if the radiograph is not taken in ulnar deviation the scaphoid will appear foreshortened.

The lateral projection shows clearly the convex surface of the

lunate parallel to the articular surface of the radius and its concave distal surface articulating with the capitate. The pisiform is seen anteriorly and it is often superimposed on the tuberosity of the scaphoid.

The anterior projection of the hand shows, in addition to the carpus, the metacarpal bones and the phalanges. Sesamoid bones are usually present in the region of the first metacarpophalangeal joint.

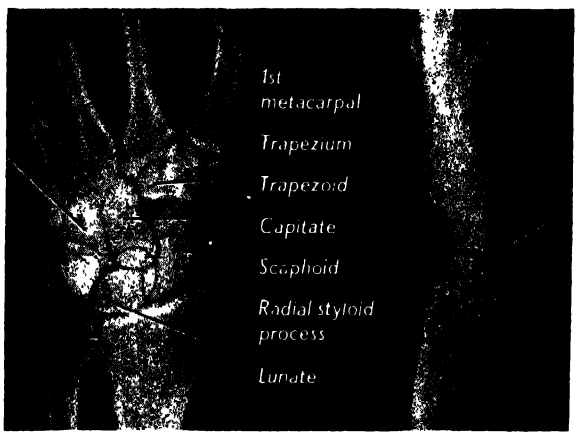


Fig. 8.13 Radiograph of region of left wrist. Anterior and lateral projections.

Ossification of the Carpus

A radiograph of the hand and wrist of a newborn child shows wide gaps between the bone ends. These gaps are occupied by unossified cartilage, for the carpal bones, the bases of the phalanges and the heads of the metacarpal bones contain no centres of bone formation at this time. Centres for the carpal bones appear roughly at yearly intervals from the appearance of the capitate in the 1st year to the 8th when the trapezoid begins to ossify; there is then an interval until the 12th year when the ossific centre for the pisiform appears. The ossific centres at the lower ends of the radius and ulna are usually seen at 2 and 8 years respectively.

For the estimation of what is called the *skeletal age* the whole hand including the terminal phalanges should be included in the radiograph in infants but for children up to about 8 years the carpus is likely to suffice; above this age the elbow will probably also be required.

BONES AND JOINTS OF THE LOWER LIMB

THE HIP BONE AND PELVIS

Each *hip* or *innominate bone* is composed of three bones, the ilium, the pubis and the ischium. The two hip bones together with the sacrum and coccyx make up the *pelvic girdle* which connects the lower extremities with the trunk.

The *ilium* is a broad somewhat fan-shaped sheet of bone, its upper border, known as the *iliac crest*, extends from the *anterior superior iliac spine* to the *posterior superior iliac spine*. Below the anterior superior spine is the *anterior inferior iliac spine* and on the medial surface of the posterior part of the bone is a large roughened area where the ilium articulates with the sacrum at the sacro-iliac joint. Below this the lower border of the bone is deeply indented and forms the greater sciatic notch. The *body* of the ilium constitutes the upper part of the *acetabulum* or socket for the hip joint.

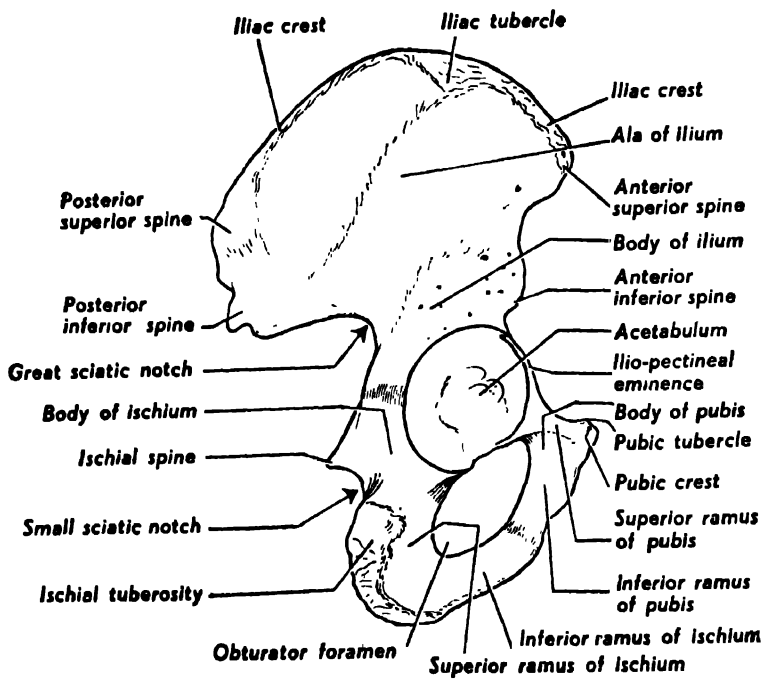


Fig. 8.14 The right hip bone — lateral aspect.

The *pubis* has a body and two rami. The *body* lies anteriorly and articulates with that of the opposite side at the pubic symphysis

which therefore lies on its medial side. The *superior ramus* runs laterally from the body to take part in the formation of the acetabulum and the *inferior ramus* runs downwards to meet the inferior ramus of the ischium.

The *ischium* is the lowest portion of the pelvis; it possesses a *body* which forms the lower part of the acetabulum and from it the *ischial spine* projects medially. The *superior ramus* projects downwards from the body and bears the broad *ischial tuberosity* on which the weight of the body is borne when sitting. The *inferior ramus* of the ischium arises from the superior ramus and extends forwards to meet the inferior pubic ramus; it is separated from this by a cartilaginous plate until about 8 years of age.

The ischium and pubis together enclose a large opening called the *obturator foramen* which is occupied during life by a membrane.

The *acetabulum* is the deep cup-shaped socket with which the head of the femur articulates and it is composed of parts of each of the three bones which constitute the hip bone. During childhood the bones are separated from each other in the acetabulum by the *triradiate cartilage*, which ossifies soon after puberty.

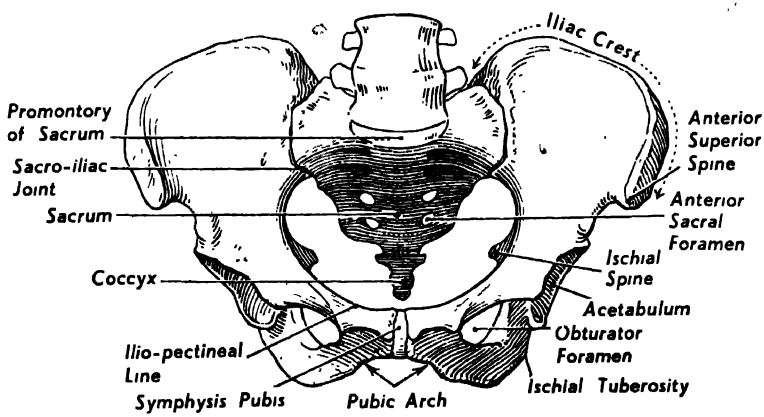


Fig. 8.15 The pelvis — anterior aspect.

THE PELVIS

The pelvis is divided into the *false pelvis* and the *true pelvis*. The false pelvis is formed by the iliac bones laterally and the sacrum posteriorly. The true pelvis is a bony ring formed by the sacrum and coccyx behind and the ischium and pubis on each side. It has an

inlet, a cavity and an outlet. The anteroposterior measurement of the pelvic inlet is called the *true conjugate* and the transverse diameter of the inlet is called the *transverse conjugate*. Both these measurements can be obtained radiographically and are of importance in obstetrics.

There are certain *sexual differences* in the pelvis. The female pelvis is wider and less deep than the male, the inlet is more circular and the subpubic arch is wider. The ischial tuberosities are further apart and the sciatic notches are wider and shallower. The female pelvis is adapted in this way for the passage of the foetal head during childbirth. In the male the bones are usually bigger and heavier but the pelvic cavity is relatively smaller.

JOINTS OF THE PELVIS

THE SACRO-ILIAC JOINT

This is a synovial joint between the articular surface of the ilium and the upper part of the lateral surface of the sacrum. The capsule is re-inforced by strong ligaments.

THE SYMPHYSIS PUBIS

The two pubic bones articulate with each other at the symphysis pubis. This joint consists of a fibrocartilaginous pad between the bones, and ligaments which unite them above and below.

BONES OF THE LOWER LIMB

THE FEMUR

The femur is the longest bone in the skeleton; it has an upper and a lower end and a roughly cylindrical shaft.

The *upper end* bears the hemispherical *head* in which is a roughened depression, the *fovea*; a ligament is attached here which binds the head of the femur to the pelvis. The head surmounts the *neck* which makes an angle of about 125° with the shaft. At the junction of the neck with the shaft the two *trochanters* are found, the *greater* on the outer aspect and the *lesser* at a lower level on the postero-medial aspect of the bone. Posteriorly between the trochanters is a prominent ridge known as the *intertrochanteric crest*.

The *lower end* of the bone is wide and bears two eminences known

as the *condyles* which are separated posteriorly by the *intercondylar notch*. At the highest part of the medial condyle the *adductor tubercle* projects and anteriorly the condyles blend with each other forming the *patellar surface* (for articulation with the patella or knee cap). There is a flattened area on the posterior surface of the bone above the condyles known as the *popliteal surface*; this forms the floor of the popliteal space through which the popliteal nerves and vessels run.

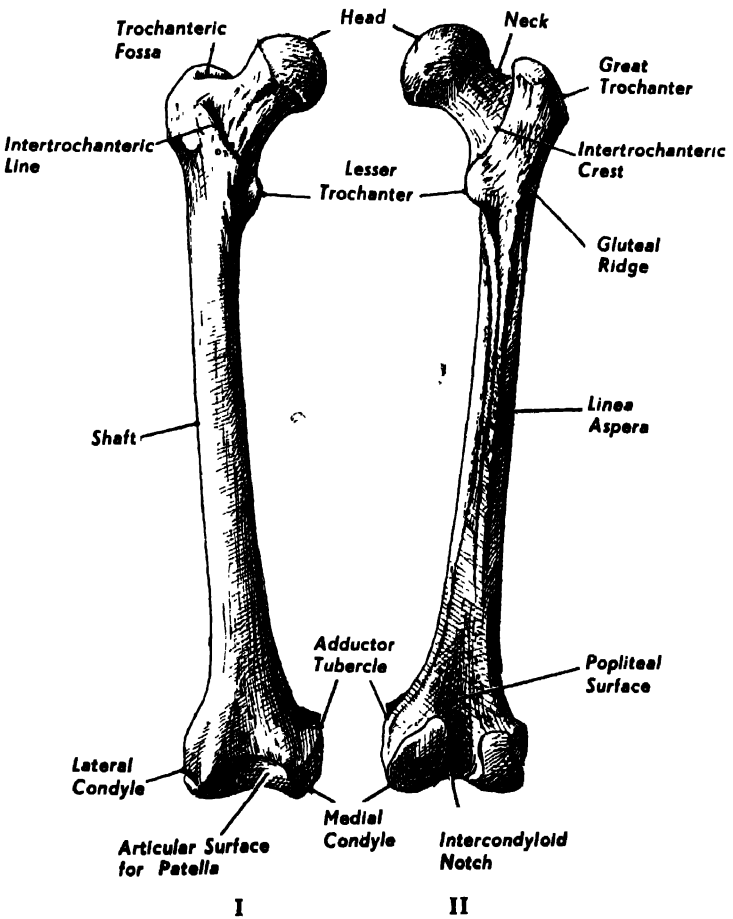


Fig. 8.16 Anterior (I) and posterior (II) surfaces of the right femur.

THE PATELLA

The patella or knee cap is a sesamoid bone in the tendon of the

quadriceps femoris muscle. It is triangular in shape and articulates posteriorly with the patellar surface of the femur when the knee is extended; when the joint is flexed it articulates with the anterior surfaces of the femoral condyles. Its anterior surface is subcutaneous but is separated from the skin by the prepatellar bursa. The quadriceps tendon blends with the bone, and the continuation of the tendon which is inserted into the tibial tuberosity is known as the patellar ligament.

THE TIBIA

The tibia is the inner of the two bones of the leg and consists of an upper and a lower end and a shaft.

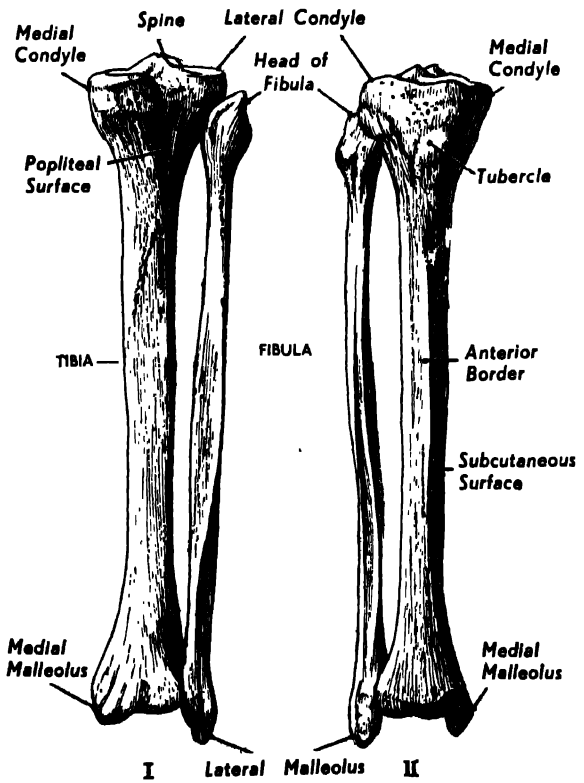


Fig. 8.17 Posterior (I) and anterior (II) surfaces of the right tibia and fibula.

The *upper end* is expanded to form the *tibial condyles* each of which has a slightly concave upper surface and takes part in the formation

of the knee joint. Between the two condyles the *tibial spine* projects upwards and ends in two pointed tubercles. Projecting anteriorly from the bone below the two condyles is the *tibial tuberosity* to which the patellar ligament is attached.

The *lower end* takes part in the formation of the ankle joint and has a downward prolongation from the medial surface known as the *medial malleolus*. On the lateral aspect of the lower end is a facet for articulation with the lower end of the fibula.

The *shaft* has a subcutaneous surface directed anteromedially and a prominent anterior border.

THE FIBULA

The fibula is the outer of the two leg bones and has an upper and a lower end and a shaft.

The *upper end* is known as the *head* and articulates with the upper end of the tibia but it does not take part in the knee joints. Certain ligaments and muscles are attached to it.

The *lower end*, known as the *lateral malleolus*, projects down beyond

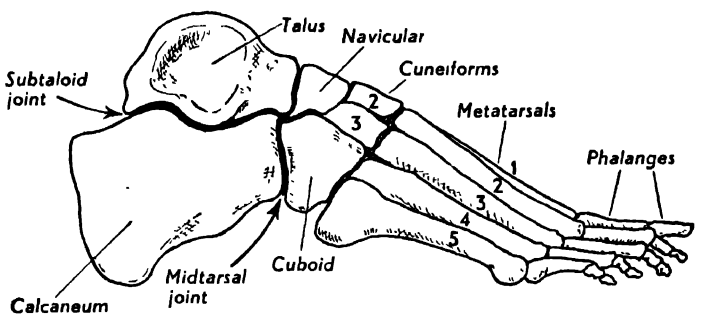


Fig. 8.18 The bones of the right foot lateral aspect.

the medial malleolus and articulates both with the lateral surface of the lower end of the tibia and with the lateral aspect of the talus.

Between the two ends is the long slender *shaft* to which are attached several muscles and the interosseous membrane which binds the tibia and fibula together.

BONES OF THE FOOT

THE TARSAL BONES

The *calcaneum* is the largest of the tarsal bones; it forms the heel

and articulates with the talus above and the cuboid in front. A process known as the *sustentaculum tali* projects medially and gives attachment to the powerful *spring ligament* which assists in the formation of the longitudinal arch of the foot. The *posterior part* of the bone is known as the *tuberosity* and the Achilles tendon (p. 118) is inserted into it. The upper surface has anterior, middle and posterior facets for articulation with the under surface of the talus. A deep groove, the *sulcus calcanei*, crosses the bone in front of the posterior articular facet.

The *talus* intervenes between the lower ends of the tibia and fibula above and the calcaneum and navicular below. It has a head, a neck and a body. The *head* projects *anteriorly* and articulates with the navicular and is separated from the body by the neck. The *body* constitutes the greater part of the bone; its upper surface takes part in the formation of the ankle joint, and below it articulates with the sustentaculum tali and posterior articular facet of the calcaneum. Projecting posteriorly from the body is the *posterior process* and some-

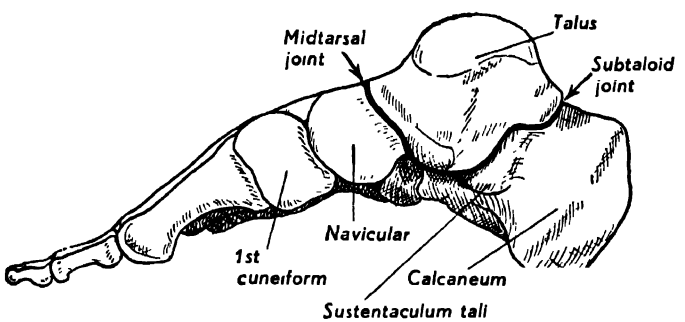


Fig. 8.19 The bones of the right foot — medial aspect showing longitudinal arch.

times part of this may remain as a separate bone, when it is known as the *os trigonum*.

The *navicular* lies on the inner side of the tarsus and intervenes between the talus behind and the three cuneiform bones in front.

The *cuneiform bones* are three in number and articulate posteriorly with the navicular and anteriorly with the medial three metatarsal bones.

The *cuboid* lies on the outer side of the tarsus and intervenes between the calcaneum behind and the two lateral metatarsals in front.

THE METATARSAL BONES

There are five metatarsal bones. The first is the thickest and the second is usually the longest. The fifth has a prominent tuberosity on the lateral side of its base.

THE PHALANGES

There are two phalanges in the great toe and three in each of the other four toes.

JOINTS OF THE LOWER LIMB

THE HIP JOINT

The hip joint is a synovial joint of the ball-and-socket variety. The rounded femoral head articulates with the deep cup-shaped acetabulum of the innominate bone. The acetabulum is deepened in the same way as the glenoid of the scapula by a ring of fibrocartilage around its circumference known as the *acetabular labrum.* Articular cartilage covers the head of the femur, except for the fovea where the *ligamentum teres* is attached. The acetabulum has a horse-shoe-shaped articular surface covered by cartilage, and a non-articular portion bridged by the transverse ligament of the hip to which the ligamentum teres is attached. The capsule of the joint is strong and is reinforced by several important ligaments which connect the femur to the ilium, the ischium and the pubis.

The movements of the hip joint are flexion, i.e. approximation of the thigh towards the abdomen; *extension*, i.e. backward movement of the thigh; *abduction*, i.e. the movement which separates the legs, and *adduction*, i.e. the movement of the thigh towards the midline; *circumduction* is a combination of all these movements. *External* and *internal rotation* need no special description.

RADIOGRAPHIC APPEARANCES OF THE HIP REGION

The radiograph may be a posterior view centred over one hip or it may be a projection of the entire pelvis so that the two hips may be compared. The subject is placed with the thigh slightly internally rotated by approximating the toes, since in this position, the neck of the femur is shown in its entirety whereas in external rotation, when the foot is directed outwards, the neck is greatly foreshortened.

The outline of the bony parts is shown and as in all synovial

joints the articulating surfaces are seen to be parallel and separated by a narrow space occupied by the articular cartilage which casts no shadow. It is customary to study '*Shenton's line*' when scrutinizing radiographs; this is the smooth curve which may be traced in the normal hip along the inferior surface of the femoral neck and upper border of the obturator foramen.



Fig. 8.20 Radiograph of the pelvis. Posterior projection.

Ossification of the Hip Region

The ossific centre for the femoral head appears during the first year and those for the greater and lesser trochanters about the fourth and ninth years respectively. During childhood the ilium, ischium and pubis are separate bones because the triradiate cartilage separates them at the acetabulum and the inferior rami of the pubis and ischium are similarly separated. In adolescence centres are also seen for the iliac crests and ischial tuberosities.

THE KNEE JOINT

The knee joint is a synovial joint of the hinge variety and three bones, the femur, the tibia and the patella enter into its formation. The condyles of the femur and the upper surface of the tibial

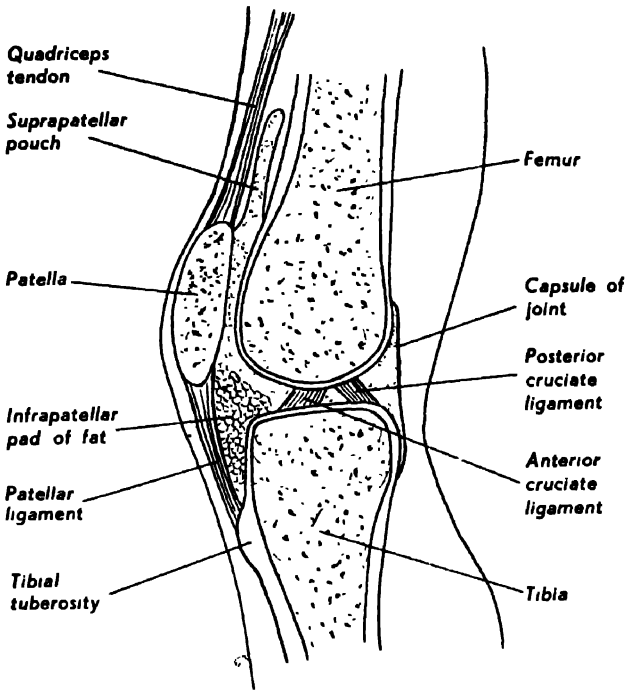


Fig. 8.21 Longitudinal section through the middle of the knee joint.

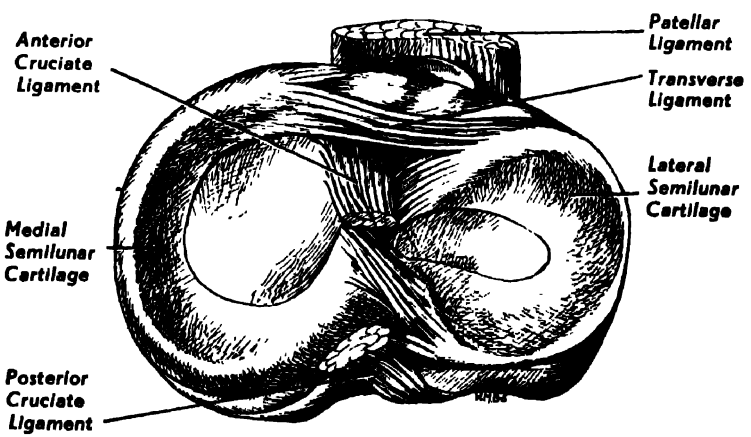


Fig. 8.22 The semilunar cartilages and cruciate ligaments of the right knee joint. The upper articular surface of the tibia is also shown.

condyles articulate with each other and the patella articulates with the anterior aspect of the lower end of the femur, the joint surfaces being covered by articular cartilage. The capsule of the joint is strengthened by several important ligaments, among them the patellar ligament and the medial and lateral ligaments. There are certain intra-articular structures the most important of which are the *anterior* and *posterior cruciate ligaments* and the *medial* and *lateral menisci* (or *semilunar cartilages*). The cruciate ligaments run obliquely from the inter-condyloid notch of the femur to the upper surface of the tibia and their function is to limit the extremes of extensions and flexion respectively. The menisci are half-moon-shaped structures attached to the upper surface of the tibial condyles. The synovial membrane is extensive and extends upwards behind the patella and lower part of the quadriceps tendon.

The movements of the knee are *flexion*, i.e. the approximation of the calf to the back of the thigh, and *extension*, i.e. straightening the limb.

RADIOGRAPHIC APPEARANCES OF THE KNEE REGION

A posterior and a lateral radiograph are usually taken. In the extended position the lower pole of the patella usually lies about ½ inch (1 centimetre) above the joint line and it is in this position that the first radiograph will be taken. The student will appreciate that although the fibula and the superior tibiofibular joint are shown they take no part in the formation of the knee joint.

The *posterior* view shows the parallel joint surfaces, the deep inter-condylar notch of the femur and the tibial spine. The head of the fibula partly overlaps the lateral tibial condyle and the patella is superimposed on the lower end of the femur. Superimposed on the lateral femoral condyle of the femur a circular shadow about 5 mm. in diameter is sometimes seen; this is the *fabella*, a sesamoid bone in the lateral head of the gastrocnemius muscle.

The *lateral* projection shows the femoral condyles partly superimposed on each other and the fibula overlapping the tibia to a variable extent. The patella lies above the anterior surface of the femoral condyles in extension, but in flexion it is seen to articulate with the distal surface of the lower end of the femur. The tibial tuberosity is seen on the anterior aspect of the bone; it is most conspicuous in adolescence when it is a separate ossific centre.



I II

Fig. 8.23 Radiograph of left knee region. (I) Posterior and (II) lateral projections.

Ossification of the Knee Region

Ossific centres for the lower femoral and upper tibial epiphyses are present at birth. Centres for the patella and head of the fibula appear at about 5 years. A separate centre for the tibial tuberosity appears at about 10 years and fuses with the upper epiphysis to form the head of the bone from which it projects as a tongue like process.

THE TIBIOFIBULAR JOINTS

The tibia and fibula articulate at their upper ends by a synovial joint, the *superior tibiofibular joint* and, at their lower ends, by a fibrous joint, the *inferior tibiofibular joint*; between their shafts stretches the *interosseous membrane.*

THE ANKLE JOINT

The ankle joint is a synovial joint of the hinge variety between

the medial malleolus, the distal end of the tibia and the lateral malleolus of the fibula above and the upper surface of the body of the talus below. The articular surfaces are covered with cartilage and the capsule is strengthened by a number of ligaments, the most important of which are those on the medial and lateral aspects.

The movements of the ankle joint are *dorsiflexion* and *plantarflexion.* In the former the foot is drawn up towards the anterior aspect of the tibia and in the latter it is moved in the opposite direction.

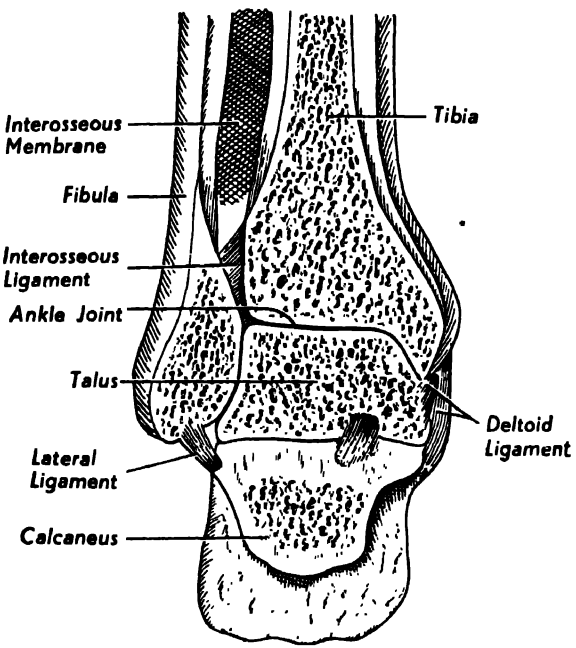


Fig. 8.24 Coronal section through the ankle joint.

JOINTS OF THE FOOT

The joint between the talus and the calcaneum is called the *subtaloid joint* and those between the talus and navicular and the calcaneum and cuboid are known collectively as the *midtarsal joint.* The movements of these joints are *inversion* in which the sole of the foot is directed inwards and the inner border of the foot is raised and *eversion* in which the outer border is raised and the sole is turned outwards.

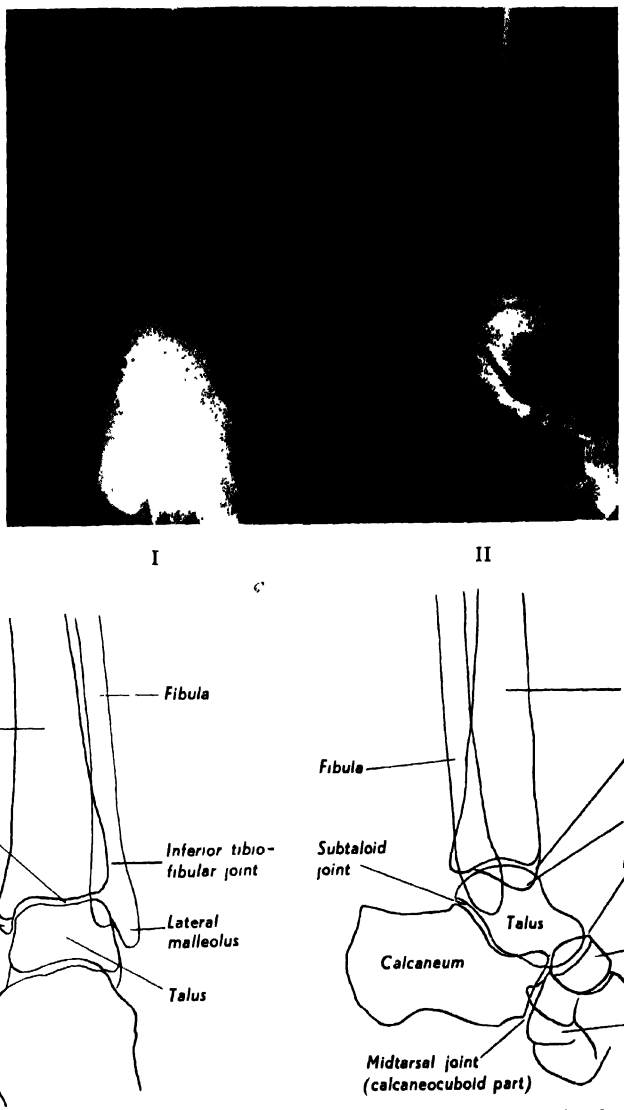


Fig. 8.25 (*a*) Radiograph of the left ankle region. (I) Posterior and (II) lateral projections. (*b*) Line drawing of (*a*).

Other joints in the foot are the intertarsal, the tarsometatarsal, the metatarsophalangeal and the interphalangeal and they do not require separate description.

THE ARCHES OF THE FOOT

There are two arches of the foot, the longitudinal and the transverse. The *longitudinal arch* (see Fig. 8.19) has a medial and a lateral side, the former is the higher and is composed of the calcaneum, the talus, the navicular, the cuneiforms and the inner three metatarsals. The lateral side of the arch is composed of the calcaneum, the cuboid and the fourth and fifth metatarsal bones. The *transverse arch* (see Fig. 8.26) is situated in the region of the tarsometatarsal joint. The arches are maintained by the shape of the bones, certain ligaments, the tendons of certain muscles of the leg and some of the intrinsic muscles of the foot.

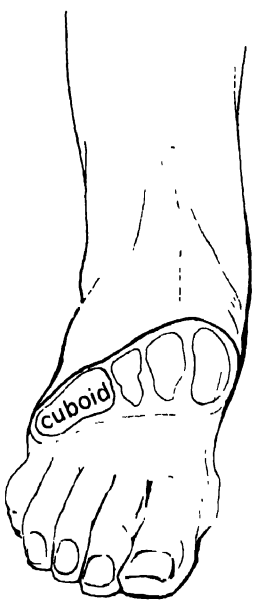


Fig. 8.26 Section through the foot to show the transverse arch.

RADIOGRAPHIC APPEARANCES OF THE ANKLE AND FOOT

The posterior view shows the lower ends of the tibia and fibula with the inferior tibiofibular joint and below these the talus grasped in the socket formed by the malleoli and the distal surface of the

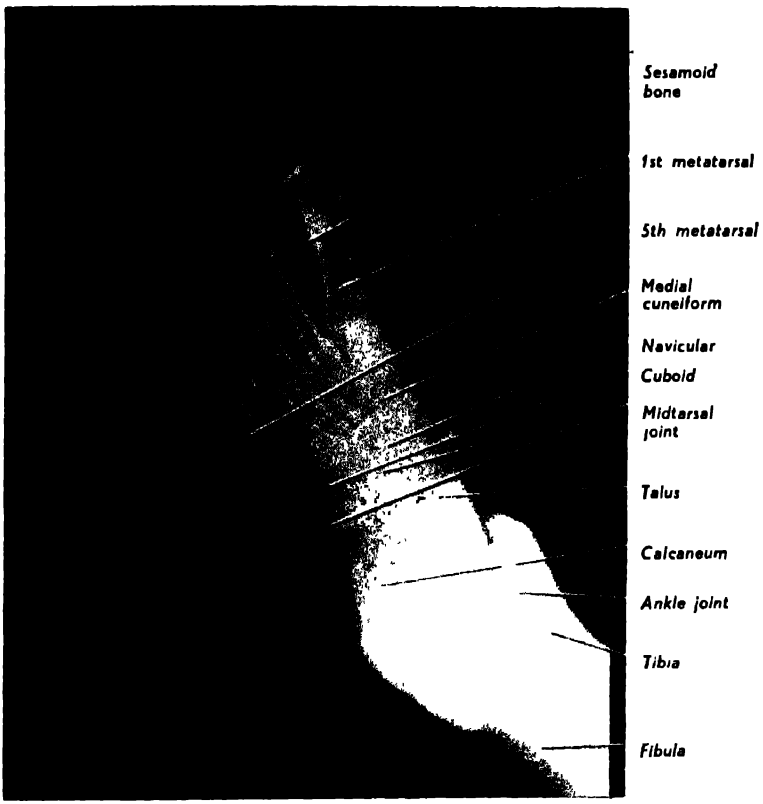


Fig. 8.27 Radiograph of the right foot. Plantar projection.'

tibia. The joint 'space' is seen separating the tibia and talus but the lateral malleolus usually overlaps the talus laterally.

The lateral projection of the ankle shows most of the tarsal bones although the cuneiforms and anterior part of the cuboid will be superimposed. The subtaloid and midtarsal joints are seen and the talus and calcaneum are viewed in profile.

In projections of the foot the tarsal bones, the metatarsals and the phalanges are seen. Sesamoid bones are present in the neighbourhood of the head of the first metatarsal bone.

Ossification of the Ankle Region

Centres are usually present in the talus, calcaneum and cuboid at birth.

The navicular is the last tarsal bone to ossify and a centre usually appears by 4 years, by this time the lower end of the tibia and fibula have also appeared and at about 10 years of age a secondary centre appears for the tuberosity of the calcaneum.

9

The Muscular System

The division of muscles into voluntary (striped) and involuntary (unstriped) varieties has already been described (Chapter 3).

A voluntary muscle has a *belly* consisting of bundles of muscle-fibres and it is attached by its *origin* and *insertion* to bone, cartilage, ligaments or skin. When a muscle contracts the fibres increase in girth and shorten thus approximating the origin, i.e. the fixed point from which it acts, to the insertion. The insertions of some muscles, for instance the flexors and extensors of the fingers, are at some distance from their bellies and in such cases fibrous *tendons* connect the muscles to their insertions. Some muscles end in sheets of fibrous tissue called *aponeuroses* (sing. aponeurosis). and part of the abdominal wall, for example, is formed by the aponeurosis of the external oblique muscle.

For movements to occur in a co-ordinated fashion contraction of the *prime mover* (as the principal muscle concerned is called) must be accompanied by relaxation of its *antagonist* (the muscle or group of muscles which have the opposite action). In some cases the full effect of the contraction of the prime mover will only be produced if *fixation muscles* steady the bone from which it arises. Thus when the shoulder is abducted the scapula must be fixed or the weight of the limb will cause it to rotate; similarly in walking the pelvis must be braced.

Muscles are covered and often ensheathed by fibrous tissue known as the *deep fascia.* The *superficial fascia* is the layer of fatty areolar tissue which intervenes between the skin and the deep fascia.

It is beyond the scope of this book to list or describe more than a few voluntary muscles.

MUSCLES OF THE HEAD AND NECK

The cranium is covered by a musculo-aponeurotic sheet and the face is composed of the muscles of facial expression and the muscles

of mastication. The superficial muscles of the neck consist of the *platysma*, the *trapezius* and the *sternomastoid*. On a deeper plane are the muscles attached to the hyoid bone, some of which pass upwards to form the floor of the mouth and others pass downwards to be inserted into the manubrium of the sternum. The deepest muscles run up the anterior aspect of the vertebral bodies and are known as the prevertebral muscles.

TRAPEZIUS

This muscle has an extensive origin which stretches from the occiput to the spinous process of the twelfth thoracic vertebra; it is

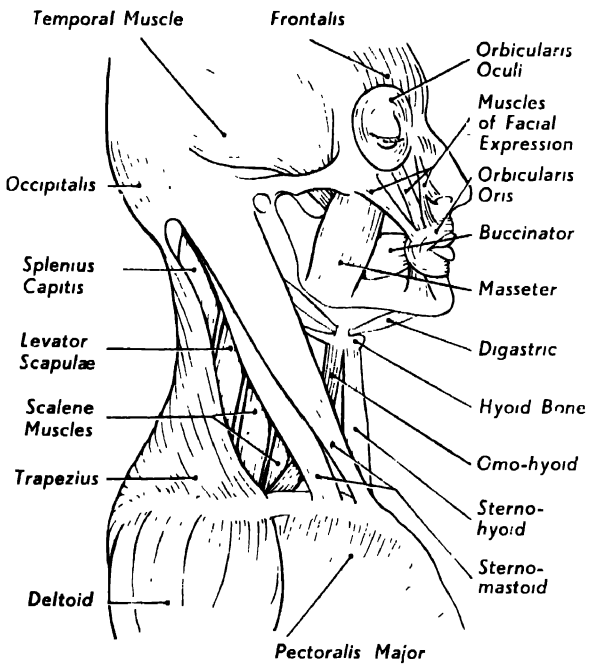


Fig. 9.1 The muscles of the face and neck.

inserted into the spine of the scapula and the clavicle. The trapezius is an elevator of the shoulder and a rotator of the scapula.

STERNOMASTOID

This muscle runs obliquely up the neck and arises from the

manubrium of the sternum and the medial third of the upper surface of the clavicle. It is inserted into the base of the mastoid process and in its course it produces a visible prominence on each side of the neck, dividing it into *the anterior* and *posterior triangles*. Its anterior margin follows approximately the course of the common carotid artery and the internal and external carotid arteries into which this vessel divides. The action of the sternomastoid when working singly, is to tilt the head towards the shoulder and rotate it to the opposite side; when acting together the muscles flex the head on the vertebral column and in forced inspiration they help to elevate the thorax.

MUSCLES OF THE TRUNK

The superficial muscles of the back are the *trapezius* and the *latissimus dorsi*. Beneath these is the *sacrospinalis* which forms a continuous band from the occiput to the sacrum, lying in the angle between the

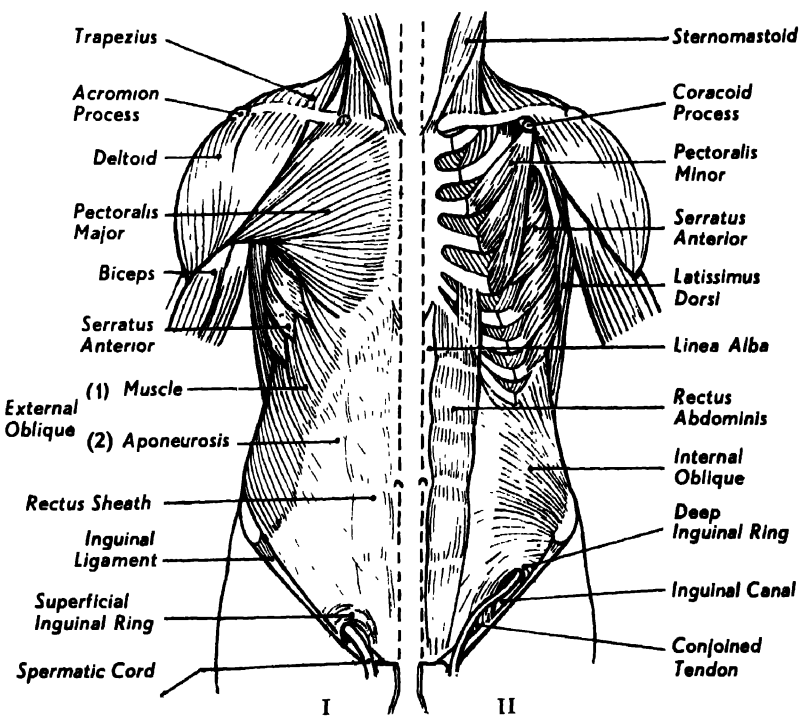


Fig. 9.2 The muscles of the front of the thorax and anterior abdominal wall. (I) Superficial. (II) Deep.

spinous processes and the transverse processes of the vertebrae, this muscle is an extensor of the spine and plays an important part in the maintenance of posture.

The anterior abdominal wall and the flanks consist of paired flat muscles, their sheaths and the aponeuroses (tendinous sheets) that arise from them. The *rectus abdominis* is one of these and each runs between the lower costal cartilages and the pubic bones. Each is enclosed in a strong sheath and the two muscles are connected in the midline by the linea alba, a fibrous band extending from the xiphoid process to the symphysis pubis.

Another muscle of the anterior abdominal wall is the *external oblique* which is more laterally situated than the rectus muscle. Its fibres run from the lower ribs to the iliac crest, to the pubis and to the aponeuroses which blend with the anterior layer of the rectus sheath.

The inguinal ligament. The lower margin of the aponeurosis of the external oblique stretches as a fibrous band between the anterior superior iliac spine and the tubercle on the anterior aspect of the body of the pubis. It corresponds in position to the overlying fold of the groin.

The inguinal canal. The lower part of the abdominal wall is perforated, in the male, by the inguinal canal which lies above the inner half of the inguinal ligament. This canal transmits several structures which pass between the scrotal* contents and the pelvis and it is one of the sites at which a 'rupture' or hernia commonly occurs. (A rupture, in this connection, is the passage of an abdominal organ or part of an organ through a weak place in the abdominal wall.)

THE DIAPHRAGM

This is a dome-shaped musculotendinous sheet which separates the abdominal and thoracic contents. It arises from the xyphisternum, the lower six pairs of ribs and costal cartilages, the fascia covering the muscles of the posterior abdominal wall and the two *crura* (sing. crus), which are tendinous origins from the bodies of the lumbar vertebrae. The muscle fibres converge to be inserted into the central tendon which they surround. The diaphragm is pierced by the inferior vena cava at the level of the eighth thoracic vertebra, by the oesophagus at the tenth and by the aorta, thoracic duct and

* The scrotum is a musculocutaneous bag in which are the testes, the male sex glands (see page 219).

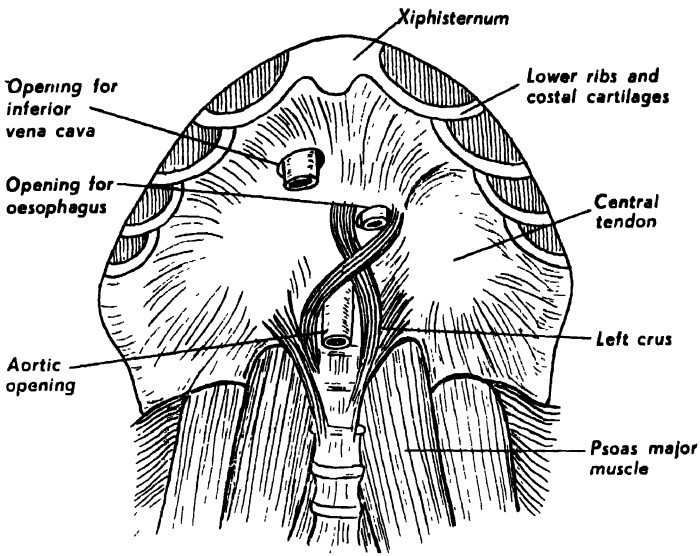


Fig. 9.3 The inferior surface of the diaphragm.

azygos vein, all of which pass through the same orifice, at the level of the twelfth thoracic vertebra.

The diaphragm is related above, on each side, to the pleura (p. 152) and in the middle to the pericardium (p. 123). These separate it from the bases of the lungs and heart respectively. The inferior surface of the diaphragm is covered by peritoneum (p. 184) and is closely applied to the upper surface of the liver, kidneys, suprarenal glands, the fundus of the stomach and the spleen.

The *functions of the diaphragm* are concerned with breathing and intra-abdominal pressure. During inspiration the diaphragm contracts and thus descends and draws air into the chest; in expiration it relaxes and the intra-abdominal pressure elevates it. Contraction of the diaphragm raises intra-abdominal pressure and it therefore assists in defaecation, micturition and parturition.

The diaphragm is supplied by the phrenic nerves, which arise from the cervical part of the spinal cord and by the lower intercostal nerves. Paralysis of one side of the diaphragm may be caused by a lesion in the neck or chest on that side involving the phrenic nerve and results in elevation and failure to descend (i.e. contract) on inspiration. Fluoroscopy is often used for studying diaphragmatic movement.

MUSCLES OF THE SHOULDER GIRDLE

These muscles are concerned with the movements of the scapula and shoulder. They form the anterior and posterior boundaries of the *axilla* as the angle between the arm and the side of the chest is called. The axilla contains lymph nodes and the blood vessels and nerves of the upper limb; it is bounded by the anterior axillary fold, made up largely of the pectoralis major, and the posterior axillary fold, largely composed of the latissimus dorsi.

PECTORALIS MAJOR AND MINOR

The pectoralis major covers nearly half of the front of the chest and as it passes laterally to its insertion it forms the anterior axillary fold. It arises from the medial half of the clavicle, from the sternum and upper seven costal cartilages and from the aponeurosis of the external oblique muscle (of the abdomen), and it is inserted into the lateral lip of the bicipital groove of the humerus. Its actions are to adduct and internally rotate the arm. Deep to the pectoralis major is the pectoralis minor which runs from the ribs to the coracoid process.

DELTOID

The deltoid covers the shoulder joint and arises from the outer one-third of the clavicle, the acromion and the spine of the scapula. Its fibres converge below to their insertion on the lateral aspect of the humerus at the deltoid tuberosity. The action of the muscle is to abduct the arm but this movement has to be initiated by the supraspinatus. Furthermore, the deltoid can only abduct to a right angle and to raise the arm higher than this rotation of the scapula is necessary.

SUPRASPINATUS

This muscle arises from the supraspinous fossa of the scapula; it runs laterally across the shoulder, where its tendon blends with the capsule of the joint, to be inserted into the highest impression on the greater tuberosity of the humerus. It acts with the deltoid as an abductor of the shoulder.

SUBSCAPULARIS

The subscapularis arises from the subscapular fossa on the anterior

aspect of the scapula and its fibres pass laterally to their insertion into the lesser tuberosity of the humerus.

MUSCLES OF THE UPPER ARM

The muscles of the arm are divided into those of the anterior or flexor compartment and those of the posterior or extensor compartment. These groups are separated by intermuscular septa which extend from the deep fascia to the bone. The anterior compartment consists of the biceps brachii and the brachialis and the posterior compartment contains only the triceps brachii.

BICEPS BRACHII

This muscle arises by two heads of origin and derives its name from this fact. It forms the muscle belly on the front of the arm; its long head arises from the supraglenoid tuberosity of the scapula as a tendon which passes laterally through the shoulder joint and the short head arises, as a tendon also, from the coracoid process. The long head occupies the bicipital groove after leaving the shoulder joint, and in the upper one-third of the arm both heads of origin give place to the muscle bellies which end in a tendinous insertion into the bicipital tuberosity of the radius. The biceps is a powerful flexor of the elbow and supinator of the forearm.

BRACHIALIS

This muscle lies in front of the elbow joint. It arises from the front of the lower half of the humerus and is inserted into the coronoid process of the ulna. The brachialis is a flexor of the elbow.

TRICEPS BRACHII

This muscle is an antagonist of the biceps brachii and covers the back of the arm. As its name suggests it arises by three heads; one is tendinous and springs from the infraglenoid tuberosity of the scapula and the other two, the medial and lateral heads, arise from the posterior aspect of the humerus. The muscle ends in a tendon which is inserted into the olecranon process of the ulna. Triceps brachii is the powerful extensor of the elbow.

MUSCLES OF THE FOREARM

The forearm is also divided into flexor and extensor compartments. The muscles in these compartments are separated into superficial and deep groups. The superficial group of flexors arises from the medial epicondyle of the humerus and the deep group arises from the interosseous membrane and the forearm bones. Many of these muscles are inserted into bones of the carpus or hand and their muscle bellies give way to tendons just above the wrist.

The superficial group of the extensor compartment arises from the lateral epicondyle and the muscles are inserted for the most part into the metacarpal bones and phalanges. The deep muscles arise from the interosseous membrane and the forearm bones and are principally inserted into the thumb.

MUSCLES OF THE HAND

There are certain muscles confined to the hand which are responsible for intricate movements of the thumb and fingers. Some of these produce a visible prominence on the radial side of the palm

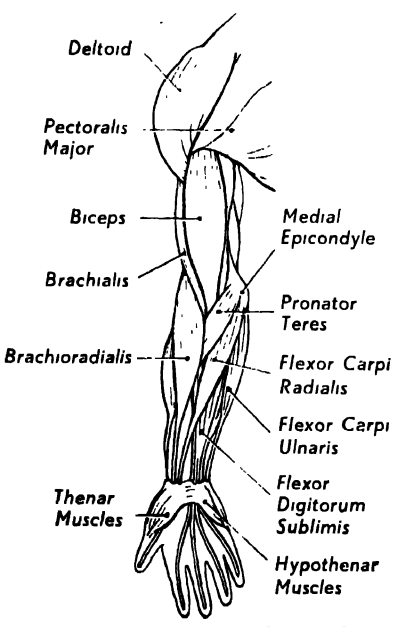


Fig. 9.4 The muscles of the right upper limb. Anterior aspect.

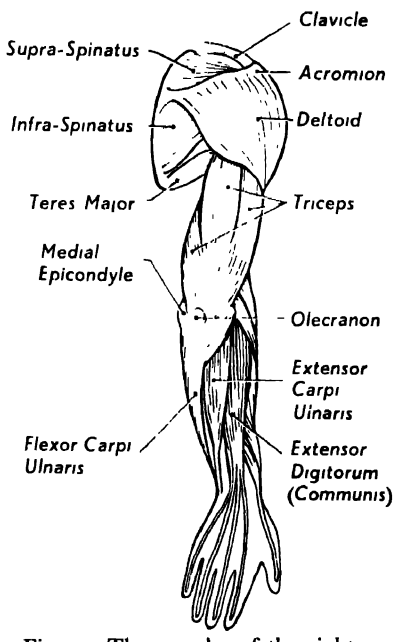


Fig. 9.5 The muscles of the right upper limb. Posterior aspect.

known as the thenar eminence and some produce an elevation on the ulnar side known as the hypothenar eminence.

MUSCLES OF THE THIGH

These may be grouped as those of the front, back and medial sides of the thigh and those of the gluteal region.

FRONT OF THE THIGH

SARTORIUS

This muscle is also known as the tailor's muscle and it stretches from the anterior superior iliac spine to the medial side of the upper tibia. It forms the roof of a groove between the vastus medialis and the adductors known as the *adductor canal*, in which the femoral vessels run. This muscle is a flexor of the hip and knee.

PSOAS

This muscle arises from the transverse processes and bodies of the lumbar vertebrae and intervertebral discs and it runs downwards and laterally, passing behind the inguinal ligament and entering the thigh as a strong ligament which is inserted into the lesser trochanter of the femur.

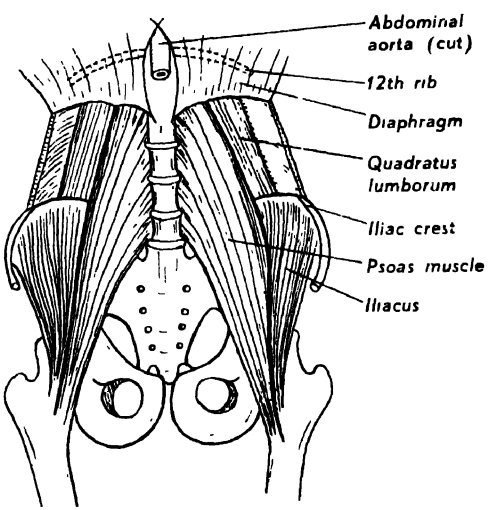


Fig. 9.6 The iliacus and psoas muscles.

ILIACUS

The iliacus arises from the iliac fossa and its fibres pass down along the lateral side of the psoas tendon into which part of it is inserted; the rest is inserted into the femur immediately below the lesser trochanter.

Both the psoas and iliacus are flexors of the hip.

QUADRICEPS FEMORIS

This muscle consists as its name suggests of four parts known as the *rectus femoris*, the *vastus medialis*, the *vastus intermedius* and the *vastus lateralis*. These all have a common tendon of insertion into the upper, medial and lateral borders of the patella from which they are connected to the tibial tuberosity by the patellar ligament.

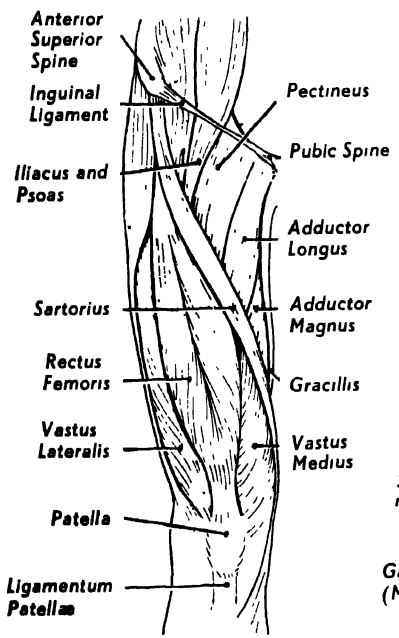


Fig. 9.7 The muscles of the right thigh. Anterior aspect.

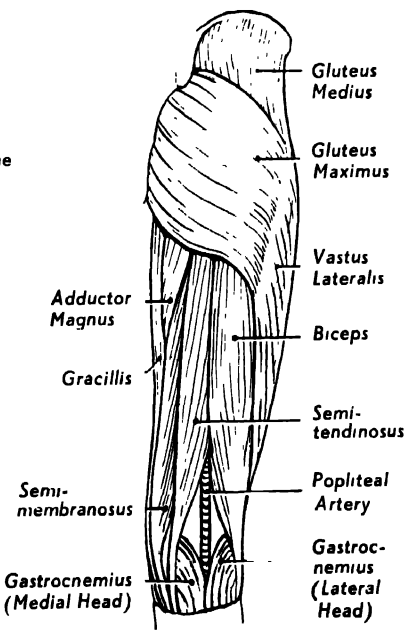


Fig. 9.8 The muscles of the right thigh. Posterior aspect.

The rectus femoris arises from the anterior inferior iliac spine and the bone immediately above the acetabulum. The vasti arise from the femoral shaft and these muscles are powerful extensors of the knee. In addition the rectus femoris is a flexor of the hip.

BACK OF THE THIGH

These muscles consist principally of those arising from the ischial tuberosity which are inserted into the upper end of the tibia and fibula. They are called the *hamstrings* and they merge into tendons which pass behind the knee lying on either side of the upper part of the *popliteal space*. The popliteal artery, vein and nerves pass through this space, the lower part of which is bounded by the two heads of the gastrocnemius muscle. The hamstrings flex the knee and extend the hip.

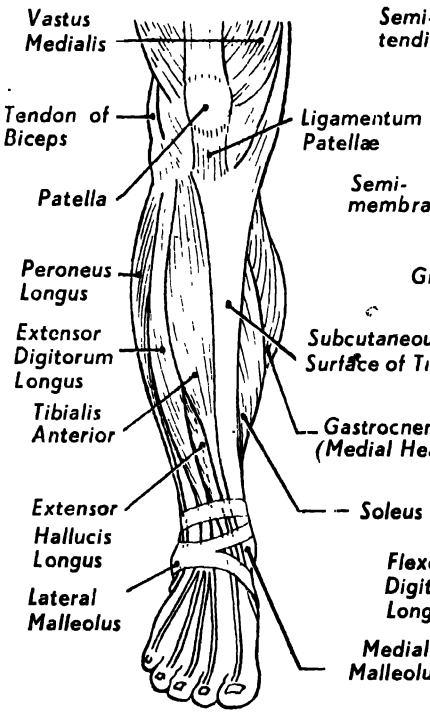


Fig. 9.9 The muscles of the right leg. Anterior aspect.

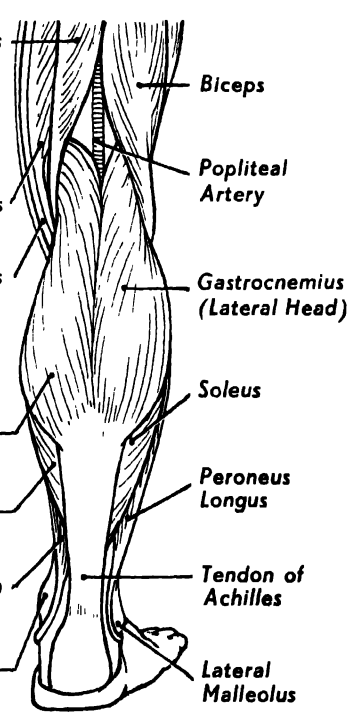


Fig. 9.10 The muscles of the right leg. Posterior aspect.

MEDIAL SIDE OF THE THIGH

The adductors of the hip constitute the muscles of the medial side of the thigh and they run from the ischium and pubis to the femur,

where they are inserted into a narrow area which stretches from the lesser trochanter above to the adductor tubercle below.

GLUTEAL REGION

The gluteal region or buttock is composed of several powerful muscles which stretch from the back of the sacrum and ilium to the upper part of the femur; their functions are to extend and abduct the thigh and they play an important part in the maintenance of posture and in walking. Under cover of these muscles are the short rotators of the hip which arise within the pelvis and are inserted into or near the greater trochanter.

MUSCLES OF THE LOWER LEG

These are divided by the bones and interosseous membrane into an anterior and a posterior compartment. The anterior muscles dorsiflex the ankle and extend the toes. The posterior group consists of a superficial layer comprising the gastrocnemius, whose two heads form the boundaries of the lower part of the popliteal fossa, and the soleus. The two muscles end in a common tendon, the *Achilles tendon*, which is inserted into the tuberosity of the calcaneum.

The deep layer of the posterior group consists of the long flexors of the toes and the tibialis posterior, the latter is a powerful invertor of the foot and plantar-flexor of the ankle.

10

The Circulatory System

The circulatory system is made up of the *heart*, a powerful muscular organ which pumps blood round the body, the *arteries* and their small branches, the *arterioles*, which carry blood away from the heart, the *veins* and the *venules* which return blood to the heart and the *capillaries* which intervene between the arterioles and the venules. The circulation consists principally of two parts, the *greater* or *systemic circulation* and the *pulmonary or lesser circulation.* Mention will be made later of the *portal circulation* which is part of the systemic.



Fig. 10.1 Valves in a vein.

1. **The Arteries.** These consist of three coats, an outer of fibrous tissue, a middle of unstriped muscle and elastic tissue and an inner of flattened endothelial cells. The calibre of the smaller arteries is under the control of the nervous system. Thus the amount of blood reaching an organ can be increased by dilating the arteries and the reverse effect is produced by constricting them; these processes are called *vasodilatation* and *vasoconstriction* respectively. The arterial *blood pressure* is determined by various factors such as the elasticity of

the arteries, the state of vasoconstriction and vasodilatation of the smaller vessels and the force of the cardiac pulsation.

2. **The Veins.** These similarly consist of three coats but they have much less muscular and elastic tissue in their walls than arteries and at intervals crescentic *valves* are found within them. These valves prevent the flow of blood in the reverse direction and thus they assist the return of blood to the heart. Blood is propelled along the veins partly by suction caused by inspiratory movements of the thorax, and partly by the massaging action resulting from the contractions of the voluntary muscles of the body during movement.

3. **The Capillaries.** These are microscopic vessels and they consist of a single layer of endothelial cells between which are scattered small openings through which white blood corpuscles can pass into the tissues. The exchange between the blood and the tissue fluid of dissolved gases, nutritive material and waste products takes place through the capillary endothelium.

THE MEDIASTINUM

The mediastinum is the space between the two pleural cavities

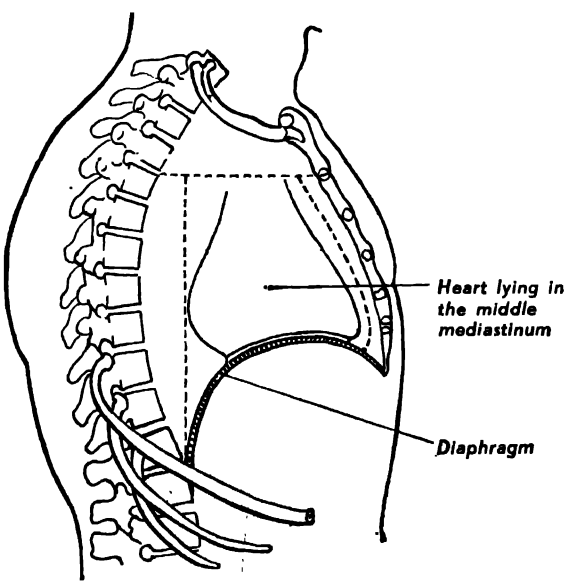


Fig. 10.2 Longitudinal section of the chest showing the superior mediastinum and the subdivisions of the inferior mediastinum (diagrammatic).

and it contains the pericardium, the heart, the great vessels, the oesophagus, the trachea, the thoracic duct, the thymus gland and lymph nodes.

It is divided into superior and inferior parts, and the latter is further divided into anterior, middle and posterior portions.

The *superior mediastinum* lies between the manubrium of the sternum in front and the upper four thoracic vertebrae behind. It contains the arch of the aorta and its branches, the innominate veins and upper half of the superior vena cava, the trachea, the oesophagus and the thoracic duct.

The *anterior mediastinum* lies between the pericardium behind and the sternum in front.

The *middle mediastinum* contains the pericardium, the heart, the roots of the great vessels, the roots of the lungs, the bifurcation of the trachea and the main bronchi.

The *posterior mediastinum* lies behind the pericardium and contains the oesophagus, the descending thoracic aorta, the thoracic duct and lymph nodes.

THE HEART

The heart is a hollow muscular organ of conical shape lying in the mediastinum (see p. 120) in a fibrous sac, the *pericardium*. It consists

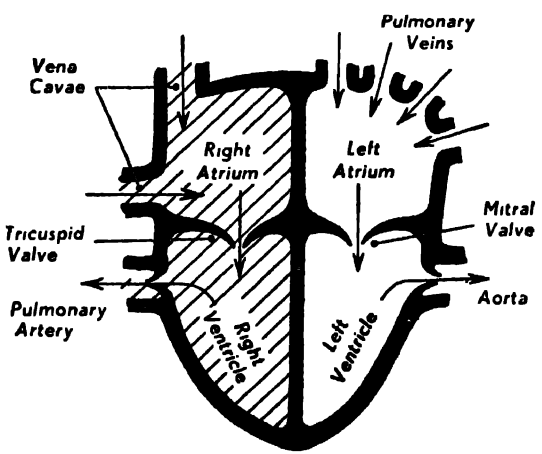


Fig. 10.3 Circulation of blood through the heart.

of right and left halves which are completely separate from each other. The right side drives the blood to the lungs and is less powerful than the left side which is the pump for the systemic circulation and has to drive the blood to the brain, the limbs, the alimentary canal, the kidneys, etc. Each half of the heart consists of two chambers which communicate through a valve; thus the right side of the heart consists of the *right atrium* into which blood flows from the systemic veins of the body (the superior and inferior venae cavae) and the *right ventricle* from which the pulmonary artery passes to the lungs. Between the two chambers of the right side is the *tricuspid valve* so named because it is composed of three cusps or flaps. The left side of the heart consists of the *left atrium* into which the pulmonary veins, carrying blood from the lungs, flow and the very powerful *left ventricle* from which the aorta conducts blood to the entire body except for that blood which goes to the lungs for the purposes of respiration. Between the left atrium and left ventricle is the *mitral valve*, so called because it consists of two cusps which are supposed to resemble a bishop's mitre.

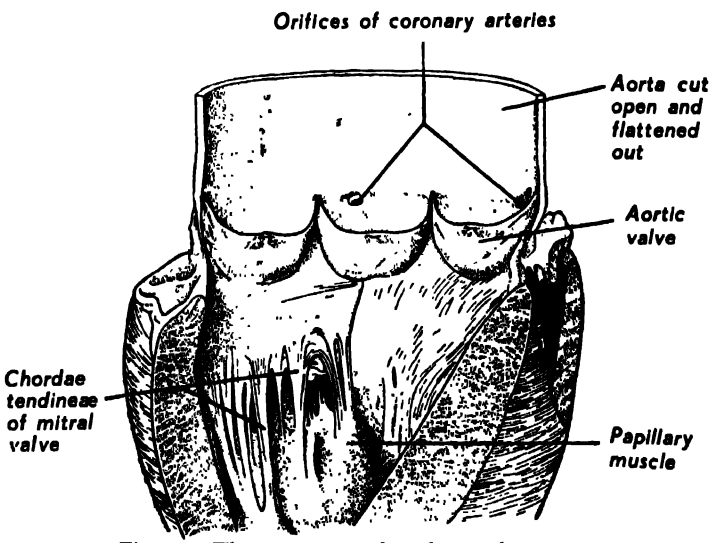


Fig. 10.4 The aorta opened to show valve cusps.

The heart is so placed that the right atrium is on the right side, the right ventricle is in front, the left ventricle is on the left side and the left atrium is behind. The pulmonary veins which discharge oxygenated blood into the left atrium therefore enter the back of the heart. The aorta leaves the left ventricle and runs upwards and to

the right but is concealed at its commencement, when viewed from the front, by the main pulmonary artery which comes from the most anterior chamber of the heart, the right ventricle. The superior and inferior venae cavae, by which the systemic venous blood is returned to the heart, enter the right atrium from above and below

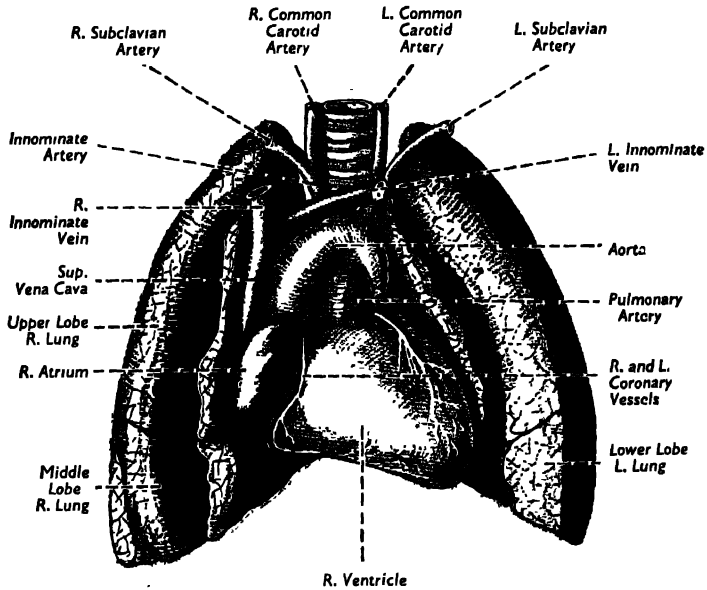


Fig. 10.5 The lungs, heart and great vessels.

respectively and form with the atrium the right border of the mediastinum.

The heart receives its own blood supply from the *coronary arteries* which leave the aorta soon after its commencement; blood is returned from the myocardium to the right atrium by the *coronary sinus*.

Structure of the Heart. The muscular wall of the heart is known as the *myocardium* and it is composed of involuntary muscle having certain microscopical characteristics which differentiate it from all other involuntary muscle. The epithelial layer which lines this is the *endocardium* and the fibrous sac which encloses the heart is called the *pericardium*. The pericardium is lined by a serous membrane (see p. 12) which is continued over the surface of the heart. These serous layers (the parietal and visceral respectively) are comparable in

arrangement and function with the pleura (p. 152) and the peritoneum (p. 184) and like them they allow the structures which they cover to move over each other without friction.

The atria are relatively thin walled because they only have to pump blood into the ventricles; each has a small pouch called an *auricle** projecting from it. The atria are separated from each other by the *interatrial septum* and the ventricles are separated by the *interventricular septum.*

The cusps of the mitral and tricuspid valves are derived from the endocardium and their free margins are connected by *tendinous cords* to the *papillary muscles* which project from the ventricular walls. There are valves also at the origins of the pulmonary artery and aorta; they consist of three flaps of half-moon shape. The purpose of all these valves is to prevent the flow of blood in the reverse direction.

The Cardiac Cycle

The heart beats automatically although it is under the control of the nervous system for it receives innervation from the vagus nerve (p. 246) and the sympathetic nervous system (p. 252). The heart rate is slowed by stimulation of the former and accelerated by stimulation of the latter. The pumping action of the heart consists of a contraction or *systole* and a relaxation or *diastole.* Both atria contract simultaneously, driving their contents into the relaxed ventricles during ventricular diastole, the ventricles then simultaneously go into systole whereas the atria go into diastole and blood flows into them from the venae cavae to be discharged into the ventricles during the next atrial systole. The usual rate of beating of the heart is 70 per minute but it increases during exercise or excitement and in various abnormal conditions.

The rhythm of the cardiac cycle results from the co-ordination of the myocardial contractions achieved by specialized nervous tissue. The cardiac impulse starts in the *pacemaker* or *sino-atrial node* situated in the wall of the right atrium, it spreads to the *atrioventricular node* which lies in the upper part of the interventricular septum and is conducted from this point by the *bundle of His* to all parts of the ventricles. The cardiac cycle is accompanied by sounds which can be detected by the stethoscope and by electrical changes which can be recorded by the electrocardiograph.

* Formerly the atria were called the auricles and the auricles were known as the auricular appendages.

The Radiographic Appearances of the Heart

(see Fig. 11.9)

In the anterior projection with the cassette at a distance of 6 feet from the X-ray tube the maximum transverse diameter of the heart shadow during inspiration in a normal subject does not usually exceed 50 per cent of the maximum internal transverse diameter of the chest. The right border of the heart and great vessels is made up of the superior vena cava, the right atrium and a short length of the inferior vena cava. The left border shows a prominence known as the *aortic knuckle* produced by the arch of the aorta. Below this the left heart border is composed of the left side of the main pulmonary artery, a short segment due to the left auricle and finally a longer segment produced by the left ventricle. The inferior border of the heart merges with the diaphragmatic shadow.

Examination in oblique projections is particularly useful in assessing the size of the left atrium and both ventricles. For the left atrium the right anterior oblique projection is used (i.e. right breast towards cassette or fluoroscopic screen) and the patient is given barium cream to swallow. The oesophagus shows impressions caused by the aortic arch, the left bronchus and pulmonary artery and below this is a long smooth curving impression due to the left atrium. In the left anterior oblique position the left ventricle is seen nearest the vertebral column and the right ventricle is seen anteriorly.

The heart may be investigated in the X-ray department by plain radiography, by fluoroscopy, by cardiac catheterization (for the purpose of taking samples of blood and measuring the pressure in various chambers) and by angiocardiography (the injection of an opaque medium into the heart followed by serial radiographs to demonstrate the opacified heart chambers).

THE CIRCULATION OF THE BLOOD

It will be recalled that the circulatory system consists of the systemic, the pulmonary and the portal circulations.

The **systemic circulation** is concerned with the passage round the body of the blood which the heart receives from the pulmonary circulation. The route taken by the blood is from the left ventricle to the aorta, its branches and their ramifications throughout the body. The blood thus reaches the capillaries and after traversing them it returns to the heart by the venules, the veins and the

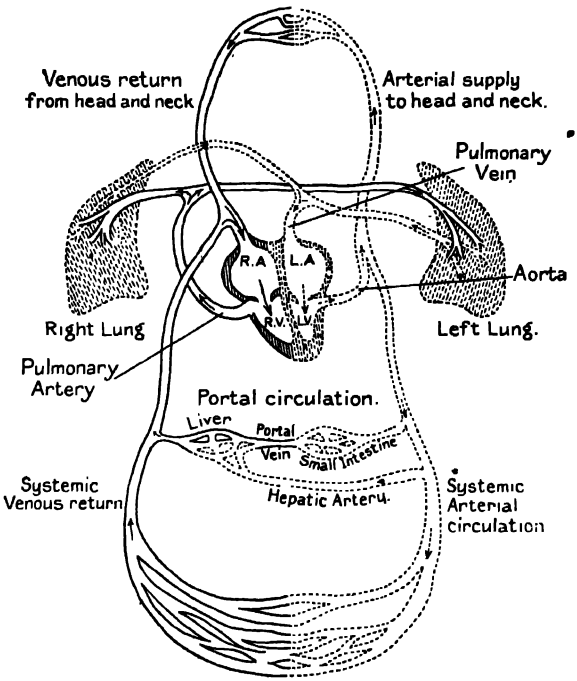


Fig. 10.6 Diagram of the circulation.

superior and inferior venae cavae which drain into the right atrium.

The object of the **pulmonary circulation** is to carry 'impure' blood (i.e. blood which is saturated with carbon dioxide and deficient in oxygen) to the lungs and to return the 'purified' blood to the heart. The blood leaves the right ventricle through the pulmonary artery which distributes it to the lungs. As it passes through the capillaries of the lungs the blood gives up carbon dioxide and acquires more oxygen and is returned to the left atrium by the pulmonary veins.

Portal circulation. Reference to Fig. 10.6 shows that the venous blood returning from the stomach and intestines does not pass directly to the inferior vena cava but, having traversed the capillaries of the bowel, it is collected into a vein called the *portal vein* which takes it to the liver. The blood then passes through the capillaries of the liver and enters the tributaries of the hepatic (liver) veins which join the inferior vena cava. This system is considered further on p. 138.

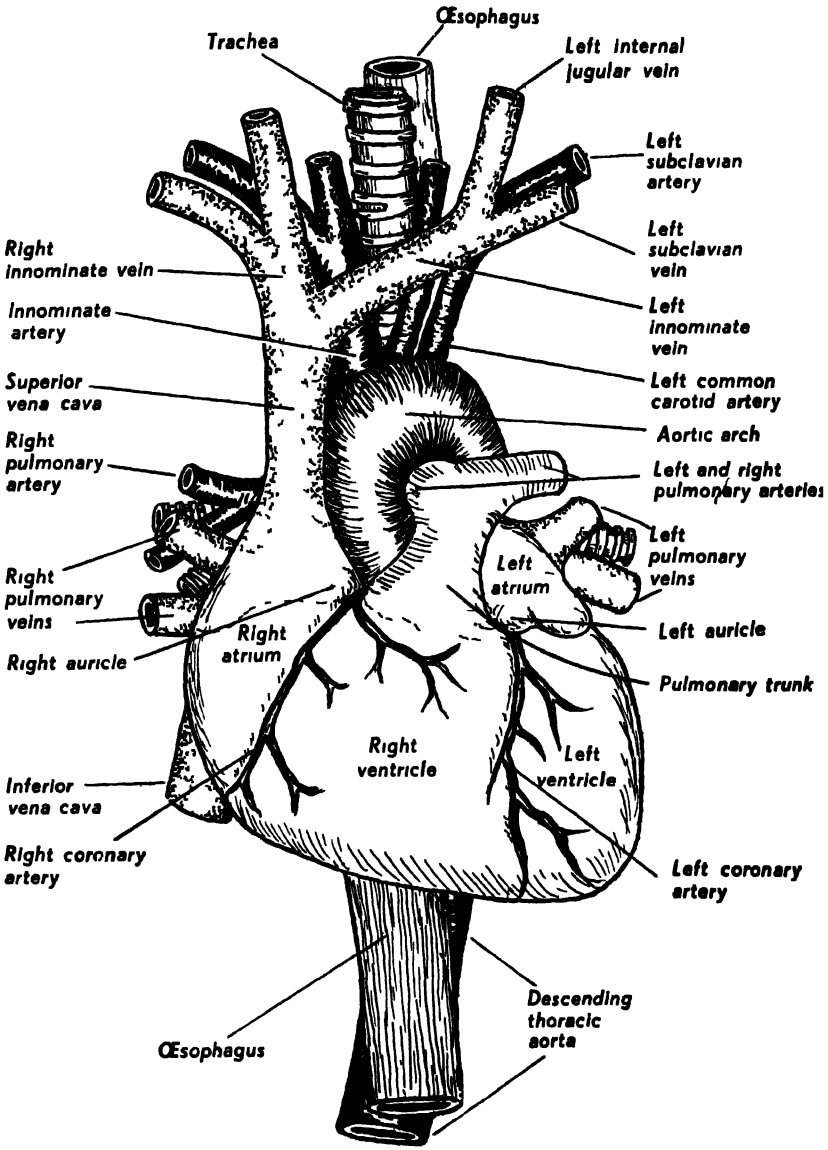


Fig 10 7 Anterior surface of the heart and great vessels

The Bronchial and Hepatic Arteries

The lungs do not depend for their nutrition on the venous blood brought to them by the pulmonary arteries nor is the liver dependent on the portal blood for its nutrition. There are *bronchial arteries* (p. 129) which supply the lungs and *hepatic arteries* which supply the liver with arterial blood.

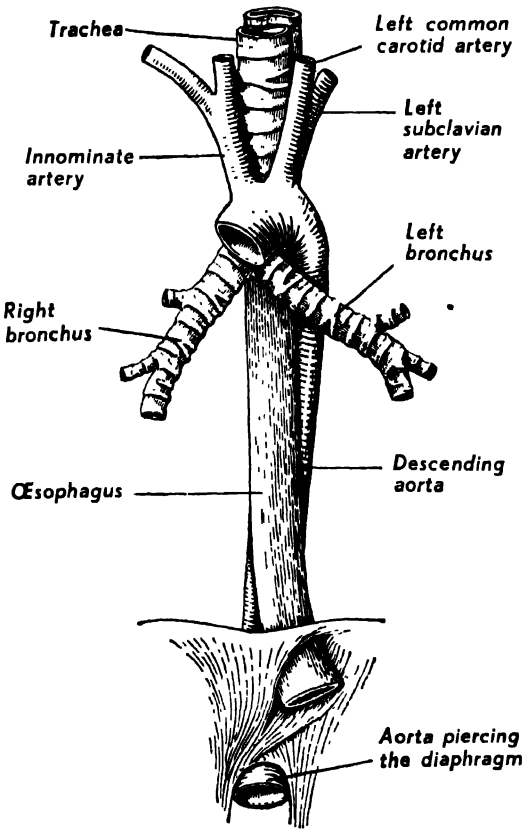


Fig. 10.8 The aorta in the thorax.

The Great Vessels of the Thorax

When the heart and great vessels are seen from the front the superior vena cava lies on the right side of the aorta and the pulmonary artery on the left.

The **superior vena cava** is formed by the junction of the two *innominate veins* each of which results from the union of the sub-clavian

and internal jugular veins of its own side. The right innominate vein runs in the same direction as the vena cava but the left crosses from left to right above the aortic arch, anterior to the left common carotid and innominate arteries and the trachea. The **inferior vena cava** enters the thorax through the diaphragm and runs a very short course before reaching the right atrium.

The **aorta** is the largest artery in the body and from its origin in the left ventricle it passes upwards, forwards and to the right and is known in this part of its course as the *ascending aorta*. Then as the *aortic arch* it curves backwards and to the left to reach the level of the body of the fourth thoracic vertebra where as the *descending aorta* it runs down behind the pericardium and to the left of the oesophagus and vertebrae until it pierces the diaphragm where it lies anterior to the vertebral column. On the left are the pleura and lung and on the right are the azygos vein and thoracic duct.

The only branches of the **ascending aorta** are the coronary arteries which supply the myocardium.

The **arch of the aorta** gives off three branches. (1) the *innominate* artery which passes to the right side of the trachea and then divides into the *right common carotid* and *right subclavian arteries* (there is no innominate artery on the left side). (2) the *left common carotid artery* comes directly off the aortic arch immediately to the left of the innominate artery and ascends into the neck on the left side of the trachea. (3) The *left subclavian artery* arises from the arch behind the left common carotid artery and ascends on the left of the trachea to the root of the neck where it turns to enter the left axilla.

The **descending aorta** gives off the *bronchial* arteries which supply the lungs. Branches are also given to the oesophagus, the pericardium and the intercostal spaces.

The **pulmonary artery,** which, the student will remember, carries de-oxygenated blood to the lungs, arises from the right ventricle and passes upwards, backwards and to the left being at first in front of the ascending aorta, then to the left of it, and finally it divides in the concavity of the aortic arch into the right and left pulmonary arteries. The *right pulmonary artery* runs behind the ascending aorta and superior vena cava and in front of the oesophagus to reach the hilum of the right lung. The *left pulmonary artery* runs in front of the descending thoracic aorta to reach the hilum of the left lung.

The **pulmonary veins,** of which there are two on each side, come from the lungs and enter the left atrium on the posterior aspect of the heart. Unlike the veins of the systemic circulation they carry oxygenated blood.

The **azygos vein** is not strictly one of the great vessels but it is convenient to describe it here. It begins in the abdomen at the level of the first lumbar vertebra and is connected at its origin with the inferior vena cava. It runs upwards in front of the vertebral bodies, passing through the aortic opening in the diaphragm; it then lies on the right of the descending aorta and behind the oesophagus until it reaches the upper part of the root of the right lung where it arches forwards and terminates in the superior vena cava. The azygos vein receives tributaries from the lumbar region, the posterior thoracic wall, the oesophagus, etc.

Arteries of the Abdomen

The **abdominal aorta** enters the abdomen through the aortic orifice in the diaphragm opposite the lower border of the twelfth thoracic vertebra and descends in front of the vertebral column on the left side of the inferior vena cava to the body of the fourth lumbar vertebra where it divides into the two common iliac arteries. It is crossed anteriorly by the left renal vein, the pancreas and the root of the mesentery.

The branches of the abdominal aorta are divided into the *visceral*

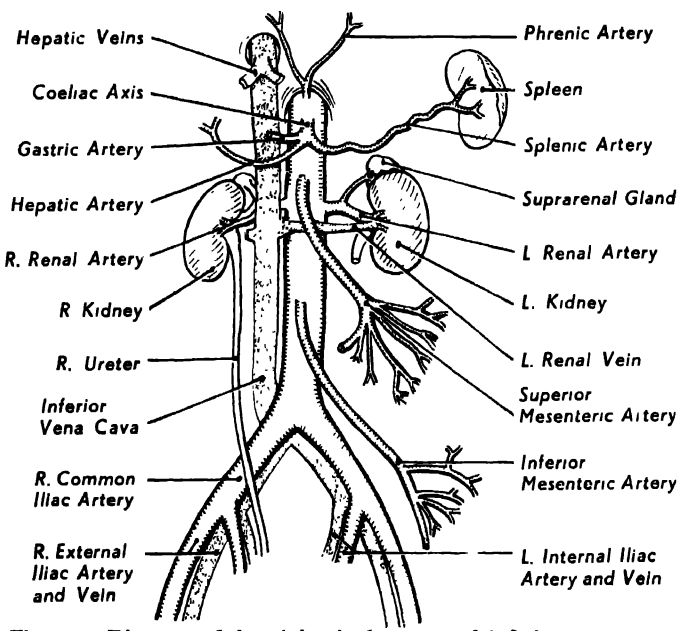


Fig. 10.9 Diagram of the abdominal aorta and inferior vena cava with some of the larger branches of each.

which supply the abdominal organs and the *parietal* which supply the abdominal wall. They are of considerable radiographic interest as they are frequently demonstrated in the examination known as aortography. The chief visceral branches are:

(1) the *coeliac axis* which supplies the liver, stomach, pancreas and spleen.
(2) the *superior mesenteric* which supplies the small intestine.
(3) the *right* and *left renal* arteries which supply the kidneys.
(4) the *inferior mesenteric* which supplies the large intestine.
(5) the *testicular* in the male and the *ovarian* in the female which supply the sex glands (gonads).

The chief parietal branches are the five paired *lumbar* arteries which pass laterally on each side.

The *common iliac arteries* are the terminal branches of the aorta and run downwards and laterally for a short distance in front of the last lumbar vertebra before dividing into the internal and external iliac arteries.

The *internal iliac artery* descends into the pelvis to supply the pelvic organs such as the rectum, bladder and uterus and other branches supply the buttock.

The *external iliac artery* runs downwards and laterally along the medial border of the psoas muscle and passes beneath the inguinal ligament to enter the thigh.

Arteries of the Head and Neck

The head and neck are supplied with arterial blood by the *common carotid* and *vertebral arteries*. The common carotid arteries divide into the *external* and *internal carotid arteries*. The external supplies the face, scalp, neck and meninges, the internal carotid artery supplies the anterior part of the brain, and the vertebral, which is a branch of the subclavian artery, supplies the posterior part. There is considerable variation in the amount of the brain which is supplied by each vessel because of the free mingling of blood which occurs in the Circle of Willis (see below).

The *middle meningeal artery* arises from the internal maxillary artery, a branch of the external carotid, and enters the skull through the foramen spinosum of the sphenoidal bone (see p. 44). It runs laterally and forwards in a groove on the squamous part of the temporal bone and divides into an anterior and a posterior branch (see p. 54).

The *common carotid arteries* differ in their mode of origin, the right arising from the innominate artery and the left directly from the aortic arch. These vessels run up the neck on either side of the trachea and thyroid gland, dividing into external and internal branches at the level of the upper border of the thyroid cartilage.

The *internal carotid artery* continues up to the base of the skull, passing through the carotid canal in the petrous portion of the temporal bone, it enters the middle cranial fossa by emerging through the upper part of the foramen lacerum (see p. 44) and at the base of the brain it divides into *anterior* and *middle cerebral arteries*. Between the anterior cerebral artery and its fellow of the opposite side is the *anterior communicating artery*.

The *vertebral artery* arises from the subclavian and ascends through the foramina in the transverse processes of the upper six cervical vertebrae to enter the skull through the foramen magnum. At the lower border of the pons the vertebral arteries of both sides join to form the *basilar artery* which ascends in the midline to the upper border of the pons where it divides into the two *posterior cerebral arteries*. These vessels supply the posterior part of the cerebrum and are connected to the internal carotid arteries by the *posterior communicating arteries*. The basilar artery also gives branches which supply the cerebellum and pons.

The circle of Willis. The blood supply of the brain is to a large extent safeguarded by the free communication which exists between the vessels derived from the internal carotid and those

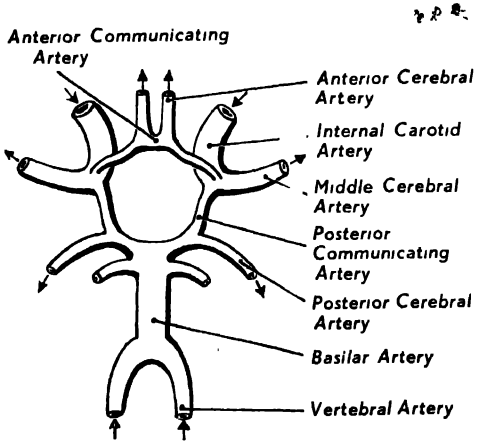


Fig. 10.10 The arterial circle (of Willis) at the base of the brain. The arrows indicate the direction of the flow of the blood.

derived from the vertebral arteries. This communication takes the form of a ring of arteries round the base of the brain; it consists anteriorly of the anterior cerebral and the anterior communicating arteries and posteriorly of the posterior cerebral arteries, the two terminal branches of the basilar artery (itself formed by the union of the two vertebral arteries), which are connected to the internal carotid vessels by the posterior communicating arteries.

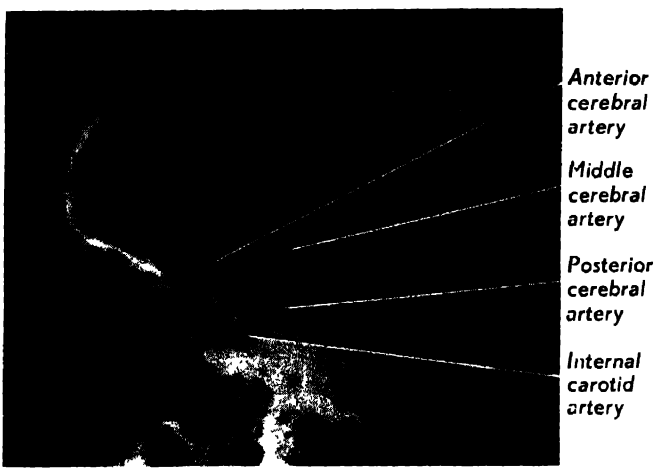


Fig. 10.11 Carotid arteriogram showing the internal carotid artery and its branches.

Arteries of the Upper Limb

The origins of the subclavian arteries have already been described (p. 129). Each passes laterally over the first rib to gain the axilla where it becomes the *axillary artery*. This artery crosses the axilla and then, renamed the *brachial artery*, it runs down the inner side of the upper arm to divide in front of the elbow joint into the *radial* and *ulnar arteries*; these run down the radial and ulnar sides of the forearm respectively and communicate with each other in the palm of the hand forming the palmar arches from which the digital branches run to the fingers.

Various branches to neighbouring structures, such as the nutrient arteries to the bones, and branches to the muscles, joints and subcutaneous tissue are given off by these vessels during their course.

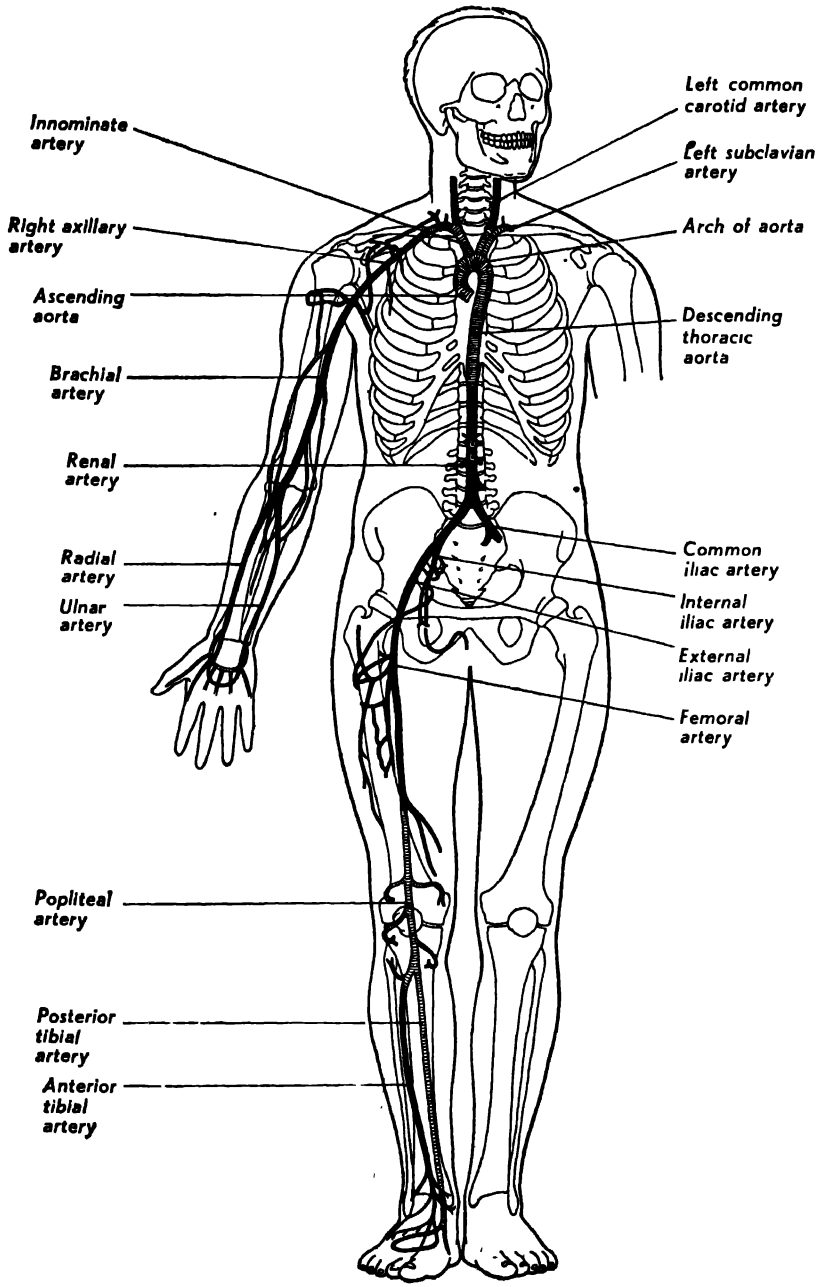


Fig. 10.12 The systemic arteries of the body.

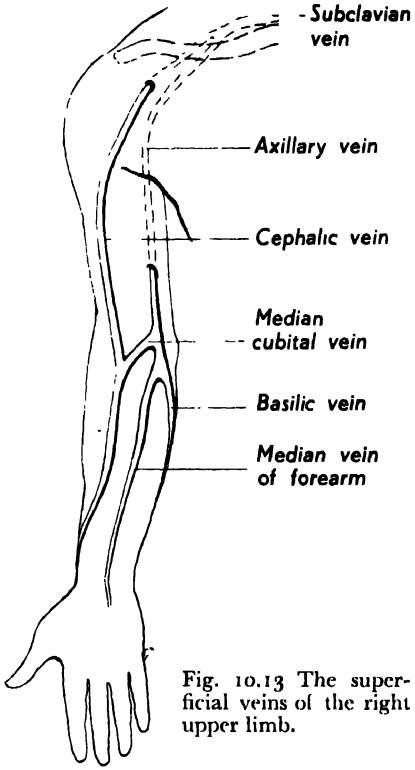


Fig. 10.13 The superficial veins of the right upper limb.

Arteries of the Lower Limb

The *femoral artery* begins at the inguinal ligament as the direct continuation of the external iliac artery. It is at first superficial so that beneath the inguinal ligament it can be palpated but it then passes into the muscular tunnel known as the adductor (Hunter's) canal (p. 115) and ends by piercing the adductor muscle group to enter the popliteal fossa. The largest branch of the femoral artery is the *profunda femoris* which is at first lateral and then posterior to the femoral artery and it supplies many of the muscles of the thigh and has connections with the popliteal artery.

The *popliteal artery* is the direct continuation of the femoral and crosses the popliteal space, at the lower end of which it divides into the *anterior* and *posterior tibial arteries*. The former runs down the front of the leg to gain the dorsum of the foot where it is called the *dorsalis pedis artery*, and the latter descends behind the tibia to reach the sole of the foot where it divides into the *medial* and *lateral plantar arteries*. The lateral plantar artery anastomoses with the terminal

branch of the dorsalis pedis artery which pierces the tissues between the first and second metatarsal bones to reach the sole of the foot. The arch so formed gives off branches which supply the toes. A large branch of the posterior tibial artery, the *peroneal*, runs close to the fibula in the lateral part of the calf.

As in the upper limb these arteries supply branches to neighbouring structures and around the main joints there are communications between the branches arising from the main vessels above the joint with others arising from below the joint; these *anastomoses*, as they are called, play an important part in the maintenance of the circulation in the limb if the main vessels become obliterated by disease.

Veins of the Head and Neck

The veins of the brain drain into large vessels in the dura mater known as *venous sinuses*. One of these, the sagittal or superior longitudinal sinus, runs backwards in the mid plane beneath the sagittal suture; all the venous sinuses drain into the transverse sinuses of which there is one on each side and these often produce a groove which can be seen in radiographs of the occipital bone (p. 56). The transverse sinuses curve laterally and downwards to the jugular foramina in the posterior fossa through which they leave the skull to become the *internal jugular veins*.

The *internal jugular veins* are deeply placed in the neck and each runs from the jugular foramen to the subclavian vein with which it unites to form the innominate vein. During their course they are closely related to the carotid arteries.

There are also some superficial veins in the neck which drain into the subclavian veins.

Veins of the Upper Limb

The deep veins of the upper limb accompany the radial, ulnar and brachial arteries and join the axillary vein.

There are several large superficial veins in the upper limb. The *cephalic* vein arises on the lateral (radial) side of the hand and ascends on the lateral side of the forearm and arm to join the axillary vein. The *basilic* vein runs from the medial (ulnar) side of the hand up the medial side of the forearm and arm to pierce the deep fascia and join the deep veins flowing with the brachial artery to form the axillary vein. In front of the elbow the cephalic and basilic veins communicate with each other and with other superficial veins by the *median cubital* vein – a vessel which is commonly used for administering intravenous injections.

The *axillary vein* crosses the axilla to become the *subclavian vein*, which runs across the first rib to be joined by the internal jugular vein to form the *innominate vein*. The left subclavian vein is joined by the thoracic duct (see p. 158) and the right receives the right lymph duct.

Veins of the Lower Limb

The deep veins consist of the *anterior* and *posterior tibial* which

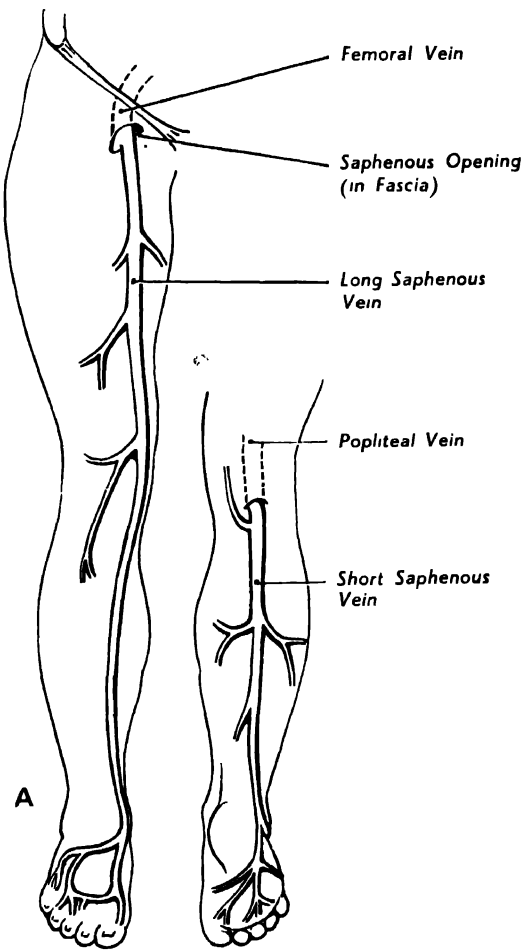


Fig. 10.14 The superficial veins of the right lower limb. A From the front. B From behind.

unite to form the *popliteal vein* which ascends through the popliteal space to the adductor canal and, running beside the femoral artery as the *femoral vein* reaches the inguinal ligament behind which it passes to become the *external iliac vein.*

The superficial veins consist of the *long saphenous vein* which runs from the foot up the inner side of the limb to join the femoral just below the inguinal ligament and the *short saphenous vein* which ascends the back of the calf to join the popliteal vein behind the knee.

Veins of the Abdomen

The *external iliac vein* is the continuation of the femoral and it ascends on the inner side of the external iliac artery to join with the *internal iliac vein* and form the common iliac vein. The two common iliac veins unite in front of the fifth lumbar vertebra to form the *inferior vena cava* (see Fig. 10.9) which ascends in front of the vertebral column, lying on the right of the abdominal aorta. It then passes behind the liver and reaches the diaphragm through which it passes at the level of the eighth thoracic vertebra. Its subsequent course has already been described (see p. 129). Among its tributaries are the renal veins (from the kidneys), the right suprarenal vein, the hepatic veins (from the liver), the right testicular and the lumbar veins.

The *azygos vein* has been described earlier in this chapter (p. 130).

The *portal vein* (see p. 126) is formed by the union of the superior mesenteric and splenic veins. The *superior mesenteric vein* drains the small intestine and the *splenic vein* drains the spleen, the lower part of the oesophagus and the stomach and it receives the *inferior mesenteric vein* which drains the large intestine. The portal vein is about 3 inches (7.5 centimetres) long and as it runs to the liver it is closely related to the hepatic artery and the common bile duct. In the liver the vein branches into smaller and smaller vessels and ultimately the blood reaches the capillaries and blood spaces known as *sinusoids.* The portal circulation thus starts in the capillaries of the bowel and spleen and ends in the capillaries and sinusoids of the liver. After passing through the liver the portal blood returns in the hepatic veins and inferior vena cava to the heart.

The anal region and the lower part of the oesophagus are drained also by the vena caval system and as communications between the portal and caval systems occur at these sites, varicosities may develop if there is obstruction to the flow of blood in the portal vein as may occur in certain types of liver disease.

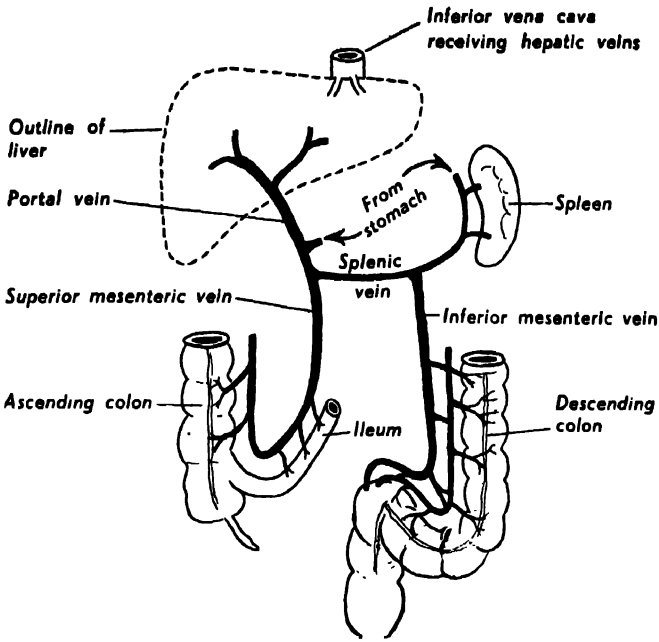


Fig. 10.15 Diagram of the portal circulation.

The portal system may be demonstrated by the injection of an opaque medium into the spleen and this procedure is often used to demonstrate the presence of varicosities in the lower oesophagus.

THE CIRCULATION OF THE BLOOD IN THE FOETUS

The foetus receives its nutrition and breathes by the placenta to which its aorta is connected by the umbilical artery and its inferior vena cava by the umbilical veins. Partially de-oxygenated blood is carried by the *former* and freshly oxygenated blood by the *latter*.

The lungs need relatively little blood before they are used for respiration (i.e before birth), so blood is short-circuited from the pulmonary artery into the aorta by the *ductus arteriosus*, and from the right side of the heart to the left by an aperture (*the foramen ovale*) between the two atria. At birth breathing is established and this results in the closing of these two communications.

THE BLOOD

Functions of Blood

Blood is a fluid substance which carries nutritive material to the

tissues and removes waste products. It carries oxygen from the lungs and receives carbon dioxide from the tissues in exchange. Varying amounts of heat are produced in different organs as a result of processes occurring within them and it is one of the functions of blood to disperse this heat around the body. Certain glands – the ductless glands – discharge their secretions (hormones) directly into the blood stream and the blood then distributes these secretions round the body. The blood also plays an essential part in the defence of the body against bacterial invasion.

Composition of Blood

An adult has about 10 pints (5 litres) of blood and analysis shows that blood consists of approximately equal quantities of a liquid part called *plasma* and solid elements called *cells* or *corpuscles*. The cells are

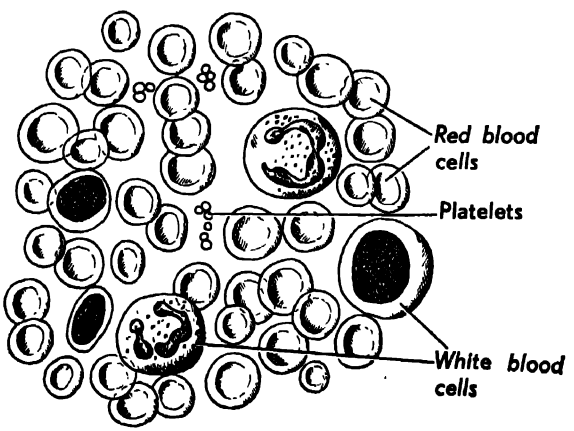


Fig. 10.16 The cells of the blood.

composed of red blood corpuscles, white blood corpuscles and platelets.

The Red Blood Corpuscles. These are the most numerous of the blood cells, there being usually about 5,000,000 per cubic millimetre. They are bi-concave circular discs and measure about 1/3200 inch (about 8μ) in diameter. Mature red corpuscles contain no nucleus. They owe their red colour to the haemoglobin which they contain.

Haemoglobin is a complex substance consisting of protein and an iron-containing pigment and it has a very strong affinity for oxygen,

with which it combines to form oxyhaemoglobin which readily gives up its oxygen to the tissues. The carbon dioxide which the blood receives in exchange for its oxygen is principally carried in solution in the plasma. Normally the blood is said to contain 100 per cent haemoglobin and in a simple iron deficiency anaemia it will contain considerably less than this.

The red blood corpuscles are manufactured in the red bone marrow, which in the infant occupies all the marrow spaces but in the adult occurs in the vertebrae, skull, ribs and pelvis. The developing red cell is nucleated until maturity is reached, that is just before it is released into the circulation.

Certain substances are required for the normal development of red blood cells and the haemoglobin which they contain. These include an adequacy of protein, vitamins B and C, iron and traces of other salts in the diet and the presence of a sufficiency of a substance known as the *anti-anaemic factor* which is formed by the combination of the *intrinsic factor*, a secretion of the stomach (p. 187), with the *extrinsic factor*, a constituent of the food known as vitamin B_{12}. The anti-anaemic factor is stored in the liver and deficiency of it results in pernicious anaemia.

The average life of the red cell is about 4 months and at the end of this time the cells are destroyed by the spleen; the iron is used again for the production of haemoglobin, but the pigment is converted into bile pigment by the liver.

The White Blood Corpuscles (or Leucocytes). These cells are bigger but much less numerous than the red cells. There are usually about 8000 per cubic millimetre and the chief varieties found are the polymorphonuclear cells, the lymphocytes and the large mononuclear cells.

The white blood cells play an important part in the defence of the body against bacterial invasion; they do this by their power of neutralizing the toxins of the organisms and by phagocytosis. *Phagocytosis* is the ability of certain cells to ingest foreign matter in the same way as the amoeba takes in food (Fig. 2.3) and is the outstanding feature of the polymorphonuclear leucocytes.

The *polymorphonuclear leucocytes* have, as their name suggests, nuclei of variable and irregular shapes. They constitute about 70 per cent of the white cells and are capable of amoeboid movement. Their chief functions are to attack and ingest bacteria and to ingest (also by phagocytosis) dead and injured material. Many leucocytes may be killed in their onslaught on invading bacteria and

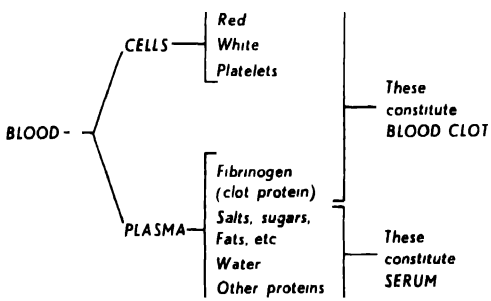
the dead cells with surrounding necrotic material constitute what is known as pus.

The *lymphocytes* comprise about 25 per cent of the white blood cells. They have a large nucleus and although they are not phagocytic they play a definite role in the defences of the body. They are made chiefly in the germ centres of the lymph nodes and spleen.

The *platelets* are about one-third of the diameter of the red cells and number about 250,000 per cubic millimetre. They are concerned with the clotting of blood and are manufactured in the bone marrow.

The average length of life of the platelets and lymphocytes is very short, the latter surviving less than one day in the blood stream. The polymorphonuclear cells survive about 30 days.

The **blood plasma** is a straw coloured, slightly alkaline fluid containing water, protein, salts and sugar. Of the proteins *fibrinogen* is the one concerned with clotting and when this is removed *serum* is left; the protein of the serum carries antibodies and special sera are used in the prevention and treatment of disease.



The **clotting of blood** is the mechanism by which blood loss is minimized at the site of wounds. It consists in the conversion of fibrinogen into fibrin, a web-like substance which fills the wound and plugs it. Red blood cells become entangled in the meshes of the fibrin plug, which expresses serum as it contracts and forms a firm clot. The conversion of fibrinogen into fibrin is a result of an enzyme liberated from the platelets and the process can be prevented by adding citrates or heparin to the blood. Many technical procedures, such as cardiac catheterization for example, could not be performed if it were not possible thus to prevent blood from clotting.

SOME EFFECTS OF RADIATION ON THE BLOOD

Long continued irradiation of the body by small doses of X-rays, such as could be received by a radiographer who persistently

ignored safety precautions, may cause changes in the blood; these result from the effects of radiation on the cells in the bone marrow and germ centres of the lymph nodes which form the red and white blood corpuscles and the platelets. One of the effects on the blood of such exposure may be depression of the white or red cell count or both. Sometimes the lymphocytes are not depressed to the same extent as the remainder of the white corpuscles owing to a compensatory increase in the production of lymphocytes by the germ centres of the lymph nodes. If exposure continues for a sufficiently long period the incidence of leukaemia, a rare malignant disease of the blood, is probably increased.

In radiotherapy if relatively large areas of the body are irradiated fairly heavily much more pronounced changes in the blood may be observed. In such a case there may be depression of all the cellular elements of the blood, the red and white cells and the platelets. The most severe manifestations of radiation effects on the blood have been seen after exposure to explosions of atomic bombs; in such cases the depression of the white cells results in diminished resistance to bacterial infections, the depression of the platelets disturbs the clotting mechanism and results in liability to haemorrhage, and the diminution of the red blood count results in anaemia. Death may result from any of these effects.

Pathological Considerations

The development of the heart is complex and many errors may occur during the process. Patients suffering from developmental abnormalities of the heart are said to have *congenital* heart disease. Certain of the complex anomalies result in the mixing of arteries and venous blood and the individual is cyanosed or 'blue'.

There are many forms of *acquired* heart disease also. Amongst these are inflammatory conditions of the endocardium, e.g. rheumatic disease of the valves – usually of the mitral, sometimes of the aortic valve and the affected valves may become constricted and incompetent.

Arteries may be affected by a degenerative condition called *atheroma* which may lead to their becoming blocked (*thrombosis*).

Diminution in the supply of arterial blood to muscles may result in cramping pain during exercise, in the legs this is called intermittent claudication (literally 'intermittent stopping'). More severe impairment of blood supply to a part may result in death of tissue, i.e. gangrene. If the coronary arteries become thrombosed severe

incapacity or death may follow as part of the heart wall may die and be replaced by fibrous tissue (*infarction*).

A collateral circulation offers an alternative route to the passage of blood along a main artery. This is because not all arterial branches end in capillaries, some unite with each other forming *anastomoses*. If a main artery becomes blocked over a short distance the collateral vessels constituting the anastomotic circulation may carry enough blood to maintain a circulation through the main vessel beyond the block thus ensuring, for instance, the survival of a limb.

Loss of blood is called *haemorrhage*. Deficiency of haemoglobin is *anaemia*. A diminution in the white cell count is called *leucopenia* and an increase in the count is a *leucocytosis* and usually accompanies infections. *Leukaemia* is a malignant proliferation of the tissue in the bone marrow which forms white blood corpuscles.

II

The Respiratory System

THE PHARYNX

The nose and nasal cavity have already been described (p. 48), The posterior nares connect the nasal cavity to the *nasopharynx*, which is that part of the pharynx lying above the soft palate. The nasopharynx also communicates with the middle ears through the *auditory* (*Eustachian*) *tubes* which open into its lateral walls; collections of lymphoid tissue known as adenoids may be present on its posterior wall.

Inhaled air passes from the nasopharynx to the *oropharynx* which is situated behind the mouth and extends from the soft palate above to the tip of the epiglottis below; it is common to both the alimentary and respiratory systems. This part and the lowest part, the *laryngopharynx*, are described with the alimentary system (see p. 179).

THE LARYNX

The larynx is the organ of voice production as well as being an air passage. It lies between the root of the tongue and the trachea, in front of the third, fourth, fifth and sixth cervical vertebrae in the adult. The skeleton of the larynx is cartilaginous and within it are the vocal cords. The hyoid bone (p. 52) lies above the larynx, to which it is attached by the thyro-hyoid membrane, and below the tongue. It is not part of the larynx but is closely related to it.

There are three single laryngeal cartilages, the epiglottis, the thyroid and the cricoid, and several paired cartilages of which the most important are the arytenoid cartilages. These and other smaller laryngeal cartilages may be seen in radiographs of the neck if calcium is laid down in them.

The *epiglottis* is a leaf-shaped cartilage which projects upwards behind the hyoid bone and the base of the tongue and in front of the opening of the larynx; it prevents food from entering the larynx during swallowing. The epiglottis is covered by mucous membrane

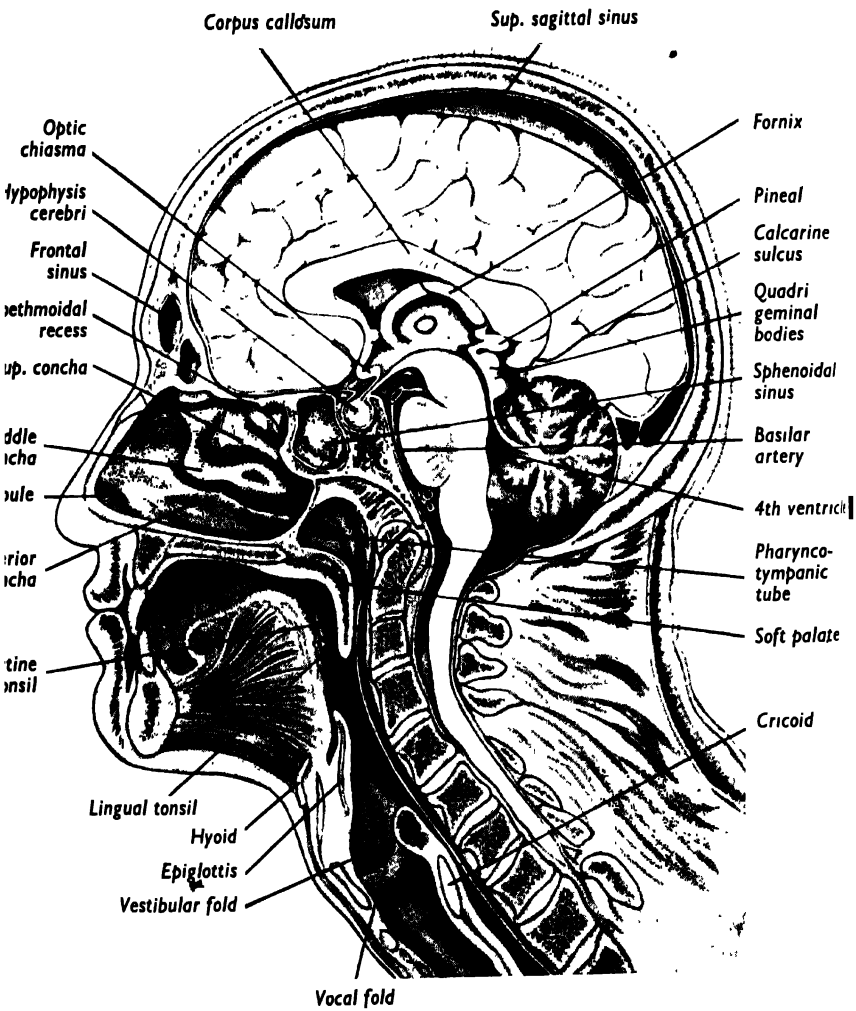


Fig. 11.1 A sagittal section through head and neck.

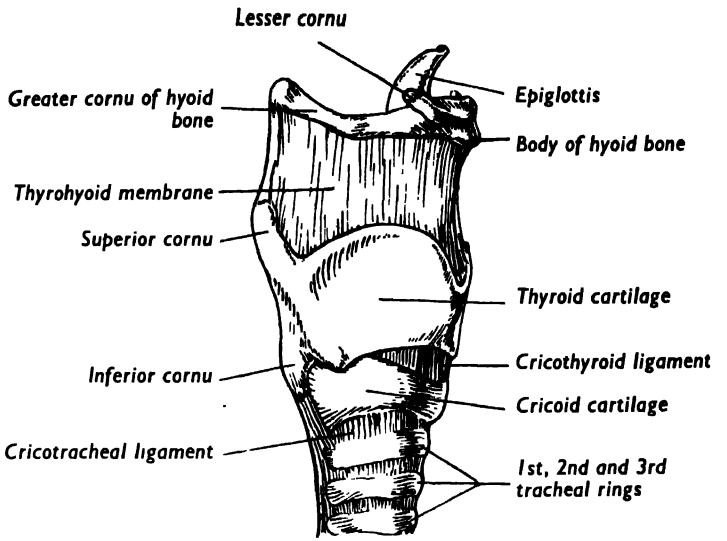


Fig. 11.2 The cartilages of the larynx.

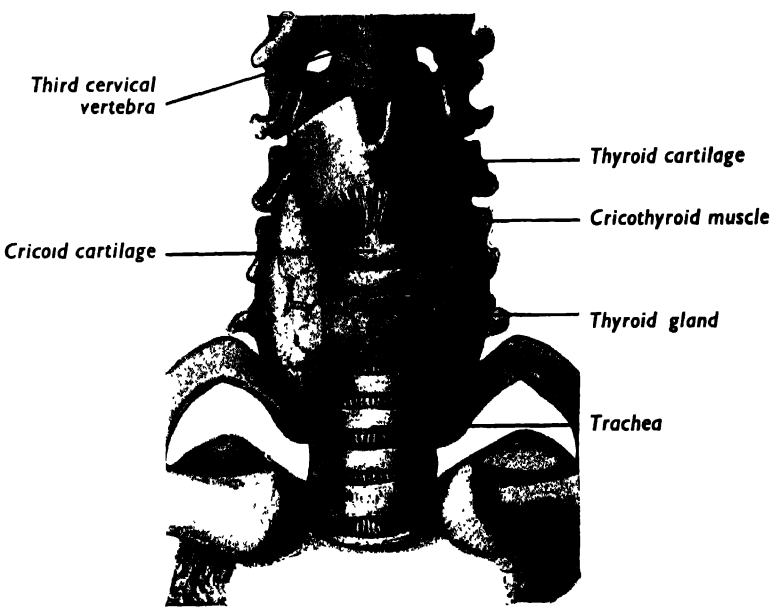


Fig. 11.3 The larynx, the thyroid gland and the cervical portion of the trachea.

which is reflected from its anterior surface to the base of the tongue; and on either side of this fold is a recess known as the *vallecula.*

The *thyroid cartilage* is the largest and consists of two laminae which fuse in the midline to form the prominence known as the Adam's apple. At the posterior borders of the laminae the superior and inferior horns project.

The *cricoid* is smaller but stronger and is described as being like a signet-ring in shape. The expanded portion lies posteriorly and the cartilage completely encircles the larynx.

The *arytenoid cartilages* are two pyramid-shaped structures on the upper surface of the posterior part of the cricoid cartilage. They partly occupy the space between the two laminae of the thyroid cartilage and form the posterior attachments of the vocal cords.

The *vocal cords* consist of one pair of *false cords* (or ventricular folds)

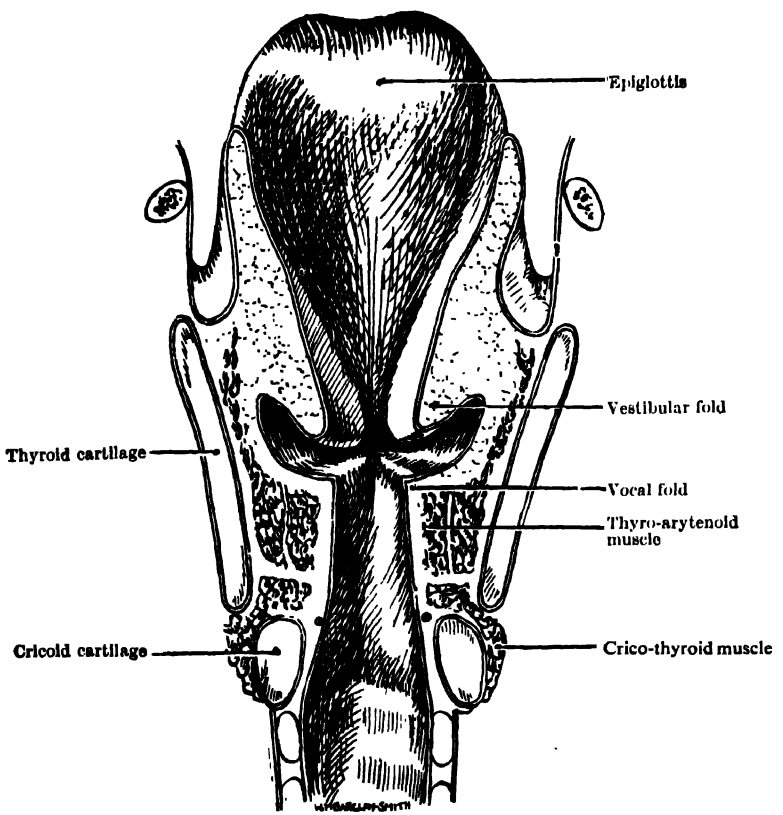


Fig. 11.4 Diagrammatic coronal section of the larynx seen from behind.

which separate the *vestibule* of the larynx from the *ventricle*; and one pair of *true cords* (or vocal folds) which separate the ventricular and *subglottic* portions of the larynx. The false vocal cords do not play any part in voice production but augment the action of the epiglottis in preventing the entry of food into the larynx during swallowing. The true vocal cords run from the arytenoid cartilages to the inner aspect of the anterior part of the thyroid laminae and they can be tightened or loosened by muscles attached to the arytenoid cartilages. The fissure between the true cords is the *glottis* and the

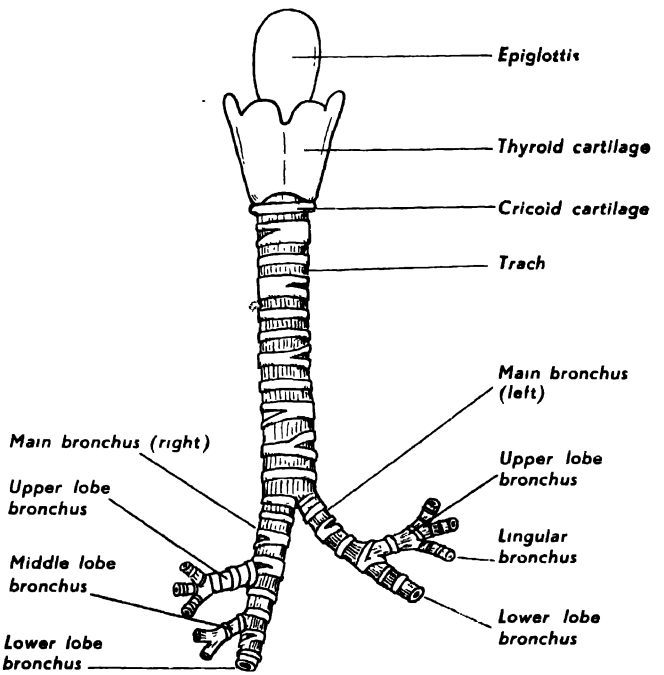


Fig. 11.5 The larynx, trachea and main bronchi — anterior aspect.

passage of air through it when the cords are tense results in the production of sounds, i.e. *phonation*.

The nasal cavities, the larynx (except for the vocal cords), the trachea and the bronchi are lined by ciliated columnar epithelium (p. 10).

THE TRACHEA

The trachea or windpipe is about 4½ inches (10-11 centimetres) in length and 1 inch (2.5 centimetres) in diameter. It extends from the sixth cervical vertebra above to the fifth thoracic vertebra below, where it divides into the two main bronchi. It consists of fibrous tissue and involuntary muscle strengthened by C-shaped rings of cartilage which surround its front and sides, but are deficient posteriorly. It is lined by ciliated columnar epithelium. The trachea runs from the neck to the superior mediastinum so it has a cervical and a thoracic portion.

Relations of the Cervical Part of the Trachea

The isthmus of the thyroid gland and the infrahyoid muscles are anterior. The lobes of the thyroid gland and the common carotid arteries are lateral. The oesophagus intervenes between the trachea and the vertebral column posteriorly.

Relations of the Thoracic Portion of the Trachea

Anteriorly the remains of the thymus gland, the left innominate vein, the arch of the aorta, and the innominate and left common

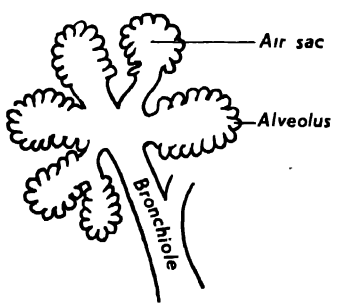


Fig. 11.6 Diagram showing termination of a respiratory bronchiole.

carotid arteries intervene between the trachea and the manubrium of the sternum. On the right side are the right lung, the right vagus nerve and the azygos vein; on the left side is the aortic arch.

THE BRONCHI

The bronchi are formed by the division of the trachea at the level

of the fifth thoracic vertebra. They diverge from each other to reach the roots of the lungs. The *right bronchus* is about 1 inch (2.5 centimetres) in length and runs a more vertical course than the left so that inhaled foreign bodies are more likely to pass into the right lung. This bronchus gives a branch to the upper lobe, and after being crossed by the right pulmonary artery it divides into the middle lobe and lower lobe bronchi. The *left bronchus* is about 2 inches (5 centimetres) in length and passes in front of the oesophagus and below the aortic arch and it divides at the root of the lung into the upper and lower lobe branches. The lingular bronchus arises from the branch to the upper lobe.

The bronchi are similar in structure to the trachea; they subdivide in the lungs and their smallest branches are the *bronchioles*. Each bronchiole terminates in an irregular sac into which numerous *alveoli* or air-cells open. The pulmonary capillaries come into intimate contact with the alveoli and the gaseous interchanges take place through their walls.

THE LUNGS

The lungs are two light, spongy and extremely elastic structures divided into lobes by fissures into which the visceral pleura dips. They are separated from each other by the contents of the mediastinum. Each has an *apex* projecting nearly 1 inch (2.5 centimetres) above the sternal end of the clavicle, a *base* resting on the diaphragmatic pleura and a costal surface which is related to the chest wall and separated from it by the costal pleura. The *medial surface* of the right lung is related to the right side of the heart and the vertebral bodies; the medial surface of the left lung is related to the left side of the heart and the arch and descending parts of the aorta. Each medial surface is also related to the root of the lung through which the bronchus and pulmonary vessels pass.

The right lung is divided into three lobes, the *upper*, *middle* and *lower*; the *horizontal fissure* separates the upper from the middle lobe and the *oblique fissure* separates the upper and middle lobes from the lower. The left lung has two lobes, the upper and lower, separated by the oblique fissure. There is no horizontal fissure and no middle lobe on the left.

The lungs consist of air-filled portions: the bronchi, the bronchioles and the alveoli, which have been mentioned above, and a fibrous tissue framework, called the *interstitial tissue*, in which blood

vessels run. They are completely enveloped, except for the lung roots, by the visceral pleura (see below).

The lungs are supplied with de-oxygenated blood by the pulmonary artery and with freshly oxygenated blood by the bronchial arteries. The pulmonary veins return freshly oxygenated blood to the left atrium whilst the bronchial veins return de-oxygenated blood to the right atrium. The pulmonary circulation is concerned with the gaseous interchanges which constitute respiration; the bronchial circulation provides for the ordinary needs of the lung tissue.

The lymphatic drainage of the lungs is considered on page 165.

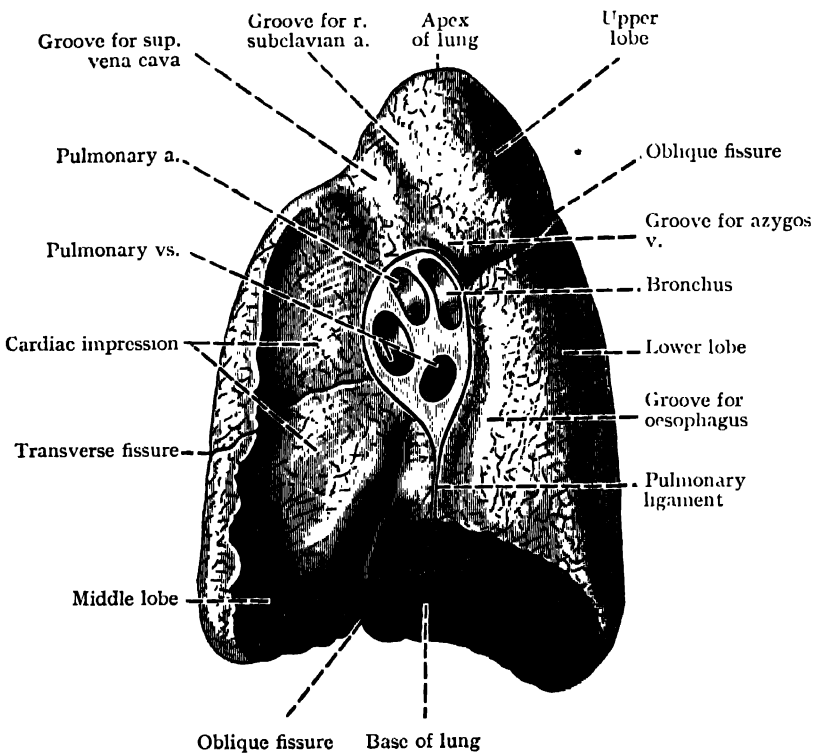


Fig. 11.7 The mediastinal surface of the right lung.

THE PLEURA

The walls of the thorax are lined by, and the surface of each lung

is covered by, a thin serous membrane called the *pleura*. That lining the chest wall is called the *parietal layer* and that covering the lung the *visceral layer*, and they are continuous with each other at the root of the lung. Between these layers is a closed space, the pleural cavity; this is a potential and not an actual cavity because the lungs are distended by atmospheric pressure so that they fill the vacuum which would otherwise exist. Thus the parietal and visceral layers of pleura are in contact and the slightly moist surfaces glide over each other during breathing.

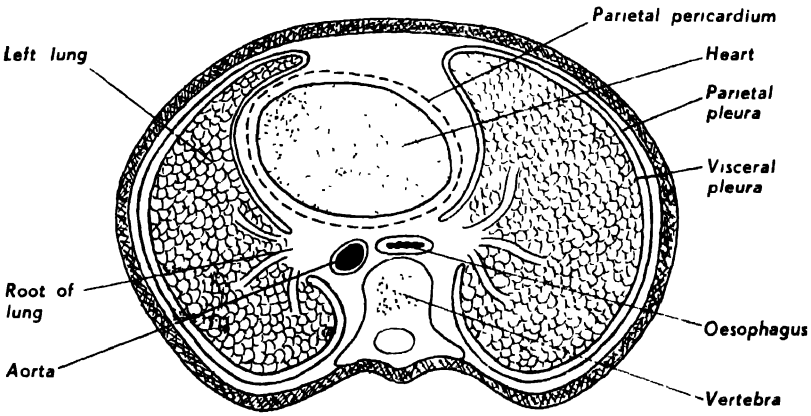


Fig. 11.8 Horizontal section of the chest showing visceral and parietal pleura, etc.

The parietal pleura may be divided into costal, diaphragmatic and mediastinal according to its position; inferiorly it dips into the angle between the diaphragm and the chest wall, the costodiaphragmatic (costophrenic) recess, reaching the tenth rib in the midaxillary line and the level of the twelfth spinous process posteriorly (p. 268).

RESPIRATION

In Chapter 2 it was explained that all living cells require oxygen for metabolism and produce carbon dioxide as an excretion. The gaseous interchange between the tissues and the blood in the capillaries is called tissue (or internal) respiration and the interchanges between the blood and air which occur in the lungs are called pulmonary (or external) respiration.

Inspired air consists of nitrogen, oxygen and a trace of carbon dioxide. Expired air has less oxygen and more carbon dioxide and is saturated with water vapour but the nitrogen content remains the same as that of inspired air.

The normal adult respiratory rate is 16 to 18 breaths per minute. The rate is controlled by the *respiratory centre* in the part of the brain known as the medulla oblongata which sends nervous impulses to the diaphragm and intercostal muscles and causes their rhythmical contraction. The respiratory centre is specially sensitive to the amount of carbon dioxide circulating in the blood and if the amount rises, as for instance during exercise, the respiratory rate and depth will increase.

The cavity of the thorax is enlarged during inspiration by depression of the diaphragm and elevation of the ribs so that air is drawn in. During expiration the ribs return to their former positions and the diaphragm relaxes and is consequently raised by the pressure of the intra-abdominal organs. These factors together with the elastic recoil of the lungs result in the expulsion of air. About 400 c.c. of air pass in and out of the lungs with each breath during quiet breathing and this is called the *tidal volume*. An additional 1500 c.c., the *inspiratory reserve volume*, can be forcibly inspired after a normal inspiration and about the same amount, the *expiratory reserve volume*, can be expelled after an ordinary breath by forced expiration. About 1000 c.c of air always remains in the lungs after forced expiration, it cannot be expelled by any expiratory effort and is called the *residual volume*. The sum total of the tidal, inspiratory reserve and expiratory reserve volumes is the volume which can be made to enter and leave the lungs by the most forcible inspiration and expiration, and this is called the *vital capacity*.

Tidal volume	400 c.c.
Inspiratory reserve volume . .	1500 c.c.
Expiratory reserve volume . .	1500 c.c.
TOTAL	3400 c.c. = Vital Capacity

Oxygen diffuses through the walls of the alveoli from the atmospheric air into the blood where some is dissolved in the plasma but most of the oxygen is carried in combination with the haemoglobin contained in the red blood cells (page 140). Oxygen is carried round the body in this form and passes to the cells and tissues by diffusion into the tissue fluid (see page 158). Carbon dioxide is carried from the tissues to the lungs partly in solution and partly in chemical

combination with salts in the blood. It diffuses through the pulmonary capillaries and the alveolar epithelium to enter the alveoli from which it is expelled by expiration.

The Radiographic Appearances of the Chest

The anterior projection should be studied and described in a systematic order and the following is suggested:

1. *Superficial soft tissues.* The nipples of either sex and the breasts in the female may be seen superimposed on the lower part of the lung fields. The sternomastoid and pectoralis major muscles may also cast shadows.

2. *Bony parts.* The posterior parts of the ribs, the costotransverse joints and the less well defined anterior parts of the ribs which, of course, do not reach the sternum, are seen. The costal cartilages may be calcified in which case they will be visible. The clavicles run laterally across the upper part of each lung field. The vertebrae are seen imperfectly and the medial borders of the scapulae may overlap the periphery of the lung fields.

3. *The diaphragm.* This structure casts a dome-shaped shadow slightly higher on the right side than the left, meeting the chest wall at an angle known as the costo-phrenic angle or recess. Beneath the left side air may be seen in the fundus of the stomach and on the right side the homogeneous shadow of the liver lies beneath the diaphragm.

4. *The trachea.* The transradiant shadow of the trachea can be seen in the midline superimposed on that of the lower cervical and upper thoracic vertebrae.

5. *The mediastinal shadow.* This is made up of the heart and great vessels. The right border consists of the superior vena cava, the right atrium and sometimes the inferior vena cava. The left border shows a prominence called the aortic knuckle caused by the arch of the aorta; below this the left margin of the pulmonary trunk (artery) and the left ventricle are the chief constituents of this part of the mediastinal shadow.

6. *The lungs.* These show the relatively dense root shadows resulting from the superimposition of the shadows of the pulmonary and bronchial vessels, the bronchi and lymph nodes. The lung fields are relatively transradiant because of the air they contain and the pulmonary vessels are seen as shadows, i.e. white markings, superimposed on them. When vessels are seen end-on they appear as small round white shadows.

It is customary to divide the lung fields into the upper, middle and lower zones which are separated by imaginary horizontal lines roughly equidistant from each other. These zones are purely

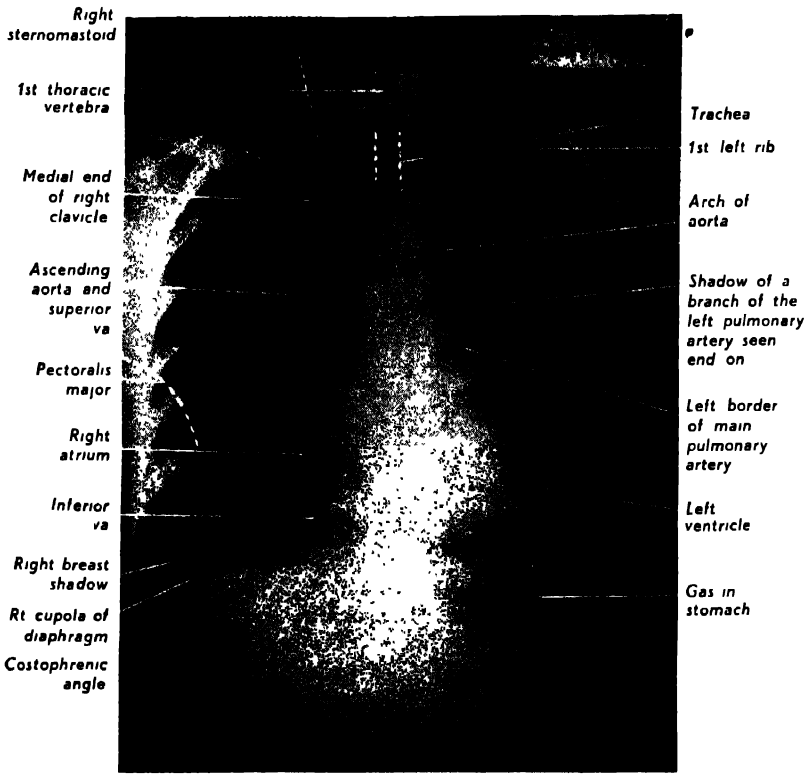


Fig. 11.9 Radiograph of the chest of a female subject. Posterior projection.

arbitrary and do not bear any particular relationship to the underlying lobes of the lung. Crossing the middle zone on the right is a very thin white line caused by the horizontal fissure which separates the upper from the middle lobe.

Pathological Considerations

Tuberculous infection occurring in childhood often involves one of the lungs and it frequently heals with calcification in the lung and hilar lymph nodes, the so-called primary complex. In adult life tuberculous lung lesions occur most frequently in the apices of the

upper lobes. Acute inflammatory conditions such as pneumonia and lung abscesses cause consolidation and thus render the affected part of the lung more opaque to X-rays. If a bronchus becomes blocked the air beyond it will be absorbed and the part of the lung to which the bronchus is running will collapse.

A *pleural effusion* is a collection of fluid in the pleural space and if the fluid is purulent it is called an *empyema*. A *haemothorax* is a collection of blood in the pleura and it is usually the result of a chest injury. Air in the pleural cavity is called a *pneumothorax* and if fluid is also present the condition is known as a *hydropneumothorax*. In the latter condition a radiograph taken with a horizontal beam will show the upper surface of the fluid as a 'fluid level'.

Obstructive emphysema is a condition in which one or both lungs are more than normally distended with air because of a hindrance to the free flow of air in a bronchus. *Bronchiectasis* is characterized by dilatation of the bronchi which may contain pus; the condition may be detected in plain radiographs of the chest but usually the instillation of opaque material into the bronchial tree (bronchography) will be required.

Many pulmonary diseases cause the patient to cough up blood and this symptom is called *haemoptysis*.

12

The Lymphatic and Reticuloendothelial Systems

THE LYMPHATIC SYSTEM

The cells of the various structures and tissues of the body are not all in close contact with the blood capillaries, so they cannot directly receive nutriment from the blood or pass their excreta into it. An intermediary is required and this is provided by the *lymph*. Lymph is derived from the blood plasma; it permeates the tissues where it is known as *tissue fluid* occupying the intercellular spaces and so comes into intimate contact with the individual cells, linking them with the neighbouring blood capillaries. The lymph is ultimately returned to the blood stream as *lymph* travelling in vessels known as *lymphatics*.

The lymphatics start as vessels of capillary size in the tissue spaces and these converge on larger vessels which, as a rule, run with the veins; like the veins they have valves to prevent the flow of their contents in the wrong direction. Most of the lymphatics of the body are too small to be visible to the naked eye. The two main lymphatic ducts, the thoracic and the right lymph ducts are, however, large enough to be seen and all the lymphatics of the body ultimately drain into either of them.

The *thoracic duct* receives lymph from both lower limbs and the abdominal organs and just before its termination it receives lymph from the left side of the remainder of the body. This duct starts in a sac-like structure, the *cisterna chyli* which measures about 4 inches (10 centimetres) long and ½ inch (1 centimetre) wide which lies in front of the first lumbar vertebra where it receives lymph from the lower limbs and abdominal organs. The thoracic duct runs upwards through the thorax between the vertebral column and the oesophagus to enter the root of the neck, where it turns to the left and joins the left subclavian vein at its junction with the left internal jugular vein. Before its termination the thoracic duct receives

lymphatics from the left side of the thorax, the left side of the head and neck and the left upper limb.

Lymph from the right upper limb, the right side of the thorax and the right side of the head and neck joins the *right lymph duct* which is only about 1½ inches (about 4 centimetres) in length and flows into the right subclavian vein.

Most of the products of fat digestion in the alimentary tract are absorbed into the *lacteals*, as the lymphatics of the small intestine are called. These run in the mesentery and end in the cisterna chyli. After a fatty meal the lymph from the intestine has a milky appearance and is called *chyle*.

The Lymph Nodes

At intervals along the course of lymphatics groups of *lymph nodes*

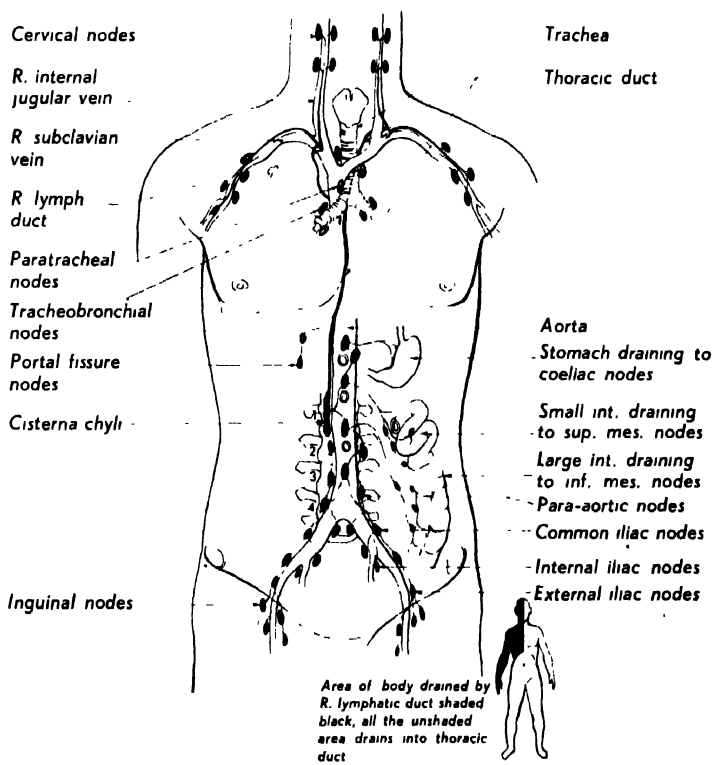


Fig. 12.1 Diagram illustrating the thoracic duct and the positions of the main groups of lymphatic nodes.

are found. These structures are also (incorrectly) called lymph glands and consist of fibrous tissue and collections of cells similar to the lymphocytes of the blood. They act as filters and extract such things as bacteria and malignant cells from the lymph. The vessels which bring lymph to the node enter the convex surface, and are called the *afferent lymphatics* and the one which leaves the concave surface or hilum is the *efferent lymphatic*. In addition to its action as a filter the node has a completely separate function for within it are the *germ centres* where the lymphocytes of the blood are manufactured and these cells are then carried to the blood stream by the lymph.

In many parts of the body the lymph vessels and nodes are arranged into superficial and deep sets. The superficial are found in the superficial fascia (the fatty layer beneath the skin) and the deep are found in the neighbourhood of the deep blood vessels. There are also collections of lymphoid tissue in the nasopharynx, the oropharynx and the small intestine, these are called the adenoids, the tonsils and the Peyer's patches respectively. Similar tissue is also present in the spleen.

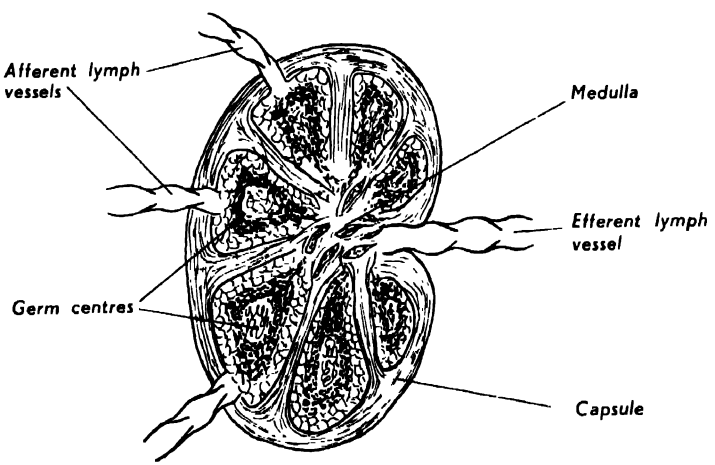


Fig. 12.2 A lymph node on section (diagrammatic). Note the valves in the lymph vessels.

The Lymph Nodes of the Head and Neck

These are divided into superficial and deep groups. The superficial may be regarded as being distributed in a ring round the base of the head and are subdivided into the *submental* which lie beneath

the chin, the *submandibular* which are between the lower border of the mandible and the submandibular salivary gland, the *auricular* which are in front of and behind the ear and the *occipital* which lie posteriorly. They drain into the deep cervical lymph nodes.

The deep nodes run with the internal jugular veins and are divided into *upper* (*superior*) and *lower* (*inferior*) sets on each side. The upper group receives lymph from the tonsils, tongue, mouth and superficial tissues and drains into the lower group.

The efferent lymphatics from the inferior group drain on the right side into the right lymph duct and on the left side into the thoracic duct.

The Axillary Lymph Nodes (See Fig. 12.5)

These drain the upper limb and the upper and outer part of the breast. They are arranged in a *lateral* group along the axillary vein, a *posterior* group along the posterior axillary margin, an *anterior* (or pectoral) group along the anterior axillary fold and an *apical* group at the apex of the axilla.

Efferent vessels go from these nodes into the right lymph duct on the right side and into the thoracic duct on the left side.

The Thoracic Lymph Nodes

These are divided into those of the chest wall, namely the *internal mammary* (anterior mediastinal), the *intercostal* and the *diaphragmatic*

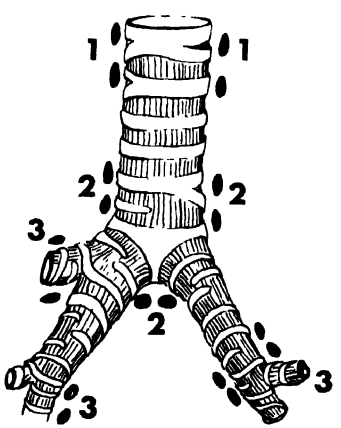


Fig. 12.3 The lymph nodes of the middle mediastinum. 1. Paratracheal. 2. Tracheobronchial. 3. Bronchopulmonary.

and those which drain the thoracic contents, the *middle* and *posterior mediastinal* nodes.

The *middle mediastinal* (See Fig. 12.3) nodes are situated along the trachea and main bronchi and receive lymph from the lungs. Those along the trachea are the *paratracheal* and those at the bifurcation of the trachea are called the *tracheobronchial nodes*. The *bronchopulmonary* nodes are found at the roots of the lungs.

The posterior mediastinal nodes are situated along the descending aorta and oesophagus and receive lymph from the oesophagus; they communicate with the middle mediastinal group.

Lymph from the mediastinal nodes on the right side drains into the right lymph duct and on the left side into the thoracic duct.

The Abdominal Lymph Nodes

These nodes are divided into the visceral and parietal groups.

The *visceral nodes* are situated along the branches of the coeliac axis and the superior and inferior mesenteric arteries close to the organs they drain, namely, the stomach, the liver, the gall bladder, the spleen, the pancreas and the intestines. Thus the gastric nodes are found along the greater and lesser curvatures of the stomach and the mesenteric nodes lie between the layers of the mesentery. Efferent lymphatics pass from these visceral nodes to the aortic nodes of the parietal group.

The *parietal nodes* are distributed around the abdominal aorta and along the external, internal and common iliac vessels. In addition to receiving lymph from the visceral nodes already mentioned these nodes also receive lymph from the lower limbs, the pelvic viscera and the organs of the posterior abdominal wall. Efferent vessels (the *right* and *left lumbar trunks* and the *intestinal trunk*) pass to the cisterna chyli.

The Inguinal Lymph Nodes

These are situated in the groin immediately below the inguinal ligament. They receive lymph from the lower limb, buttock and external genital organs; efferent lymphatics pass to the iliac group of parietal abdominal nodes.

THE ADENOIDS

The lymphoid tissue on the posterior wall of the nasopharynx (p. 145) is called the adenoids if it is enlarged.

THE TONSILS

There are two oval masses of lymphoid tissue lying in the lateral walls of the oropharynx between the pillars of the fauces called the tonsils. They merge with lymphoid tissue on the posterior part of the tongue.

PEYER'S PATCHES

The collections of lymphoid tissue in the lower part of the ileum are known as Peyer's patches.

Lymph Drainage of Certain Structures*

1. *The tonsil.* Lymph drains into the upper deep cervical nodes of the same side.

2. *The tongue* (see Fig. 12.4). Lymph from the dorsum of the anterior part of the tongue and the entire posterior portion of the organ passes directly into the upper and lower deep cervical nodes of *both* sides. Lymph from the tip of the tongue passes first to the submental nodes and from each side of the tongue it goes first to the submandibular group of the same side; from these sets of superficial nodes the lymph passes to the deep cervical nodes.

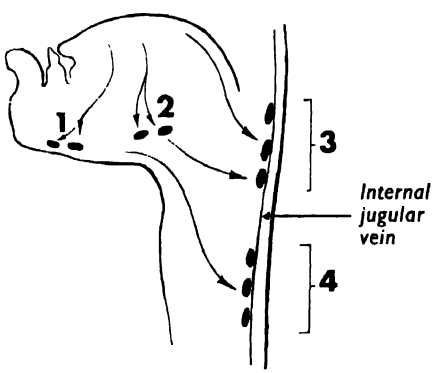


Fig. 12.4 Lymph drainage of the tongue (diagrammatic). 1. Submental nodes. 2. Submaxillary nodes. 3. Upper deep cervical nodes. 4. Lower deep cervical nodes.

The fact that much of the tongue drains to the lymph nodes of both sides is of great clinical importance since malignant disease of the tongue is likely to require treatment of the lymph nodes on each

* To avoid repetition of matter which has already been presented in this chapter the lymph drainage is only described as far as the regional lymph nodes.

side of the neck unless the lesion is a very early one and is limited to the lateral border of the anterior two-thirds of the organ.

3. *The thyroid gland.* The upper part of the gland drains into the upper deep cervical nodes and the lower part of the gland drains into the paratracheal nodes of the middle mediastinum.

4. *The breast.* (See Fig. 12.5) A network of lymphatics is present in the breast substance and beneath the areola (the pigmented area in the centre of which is the nipple). The lymphatics which leave the breast communicate with those in the deep fascia overlying the pectoralis major muscle. From the upper and outer parts of the breast efferent lymphatics pass into the anterior (pectoral) and apical groups of axillary nodes. Efferent lymphatics from the medial part of the breast drain into the internal mammary (anterior mediastinal) nodes and also some lymphatics pass across the midline to communicate with those of the inner part of the opposite breast. From the lower part of the breast lymphatics pass to the anterior abdominal wall.

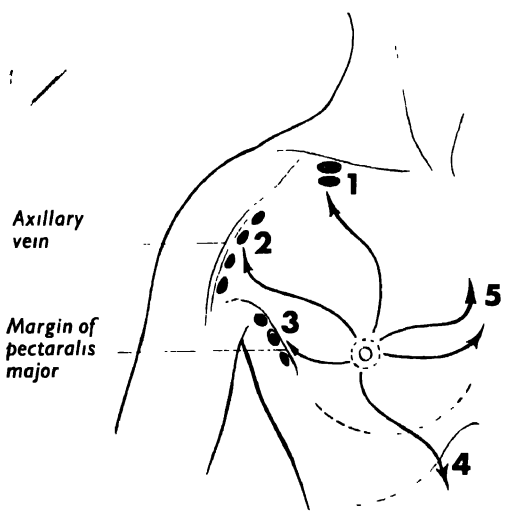


Fig. 12.5 Lymph drainage of the breast (diagrammatic). 1. Apical axillary nodes. 2. Lateral axillary nodes. 3. Pectoral nodes. 4. To abdominal wall. 5. To anterior mediastinal nodes along internal mammary artery and communications with opposite breast. *Note* no attempt has been made to indicate the structures overlying the various lymph nodes.

Cancer of the breast may be treated by a radical operation in which an effort is made to remove all the tissue which may be

affected and diseased; in this the surgeon removes the breast, the deep fascia and pectoralis major, and all the axillary lymph nodes.

5. *The lungs.* The pulmonary lymphatic vessels consist of a superficial network beneath the visceral pleura and a deep network which follows the bronchi and pulmonary vessels. Both transmit lymph to the nodes of the middle mediastinum, i.e. the bronchopulmonary and tracheobronchial nodes (see Fig. 12.3). Communications with the posterior mediastinal and paratracheal nodes also occur.

6. *The small intestine.* The lacteals (see p. 159) conduct the lymph from the small intestine to the pre-aortic nodes at the origin of the superior mesenteric artery.

7. *The colon.* Lymph passes from the colon to nodes along the mesenteric vessels and thence to the pre-aortic nodes at the origins of the superior and inferior mesenteric arteries.

8. *The rectum and anal canal.* Some lymphatics pass to the nodes situated along the internal iliac (hypogastric) and common iliac arteries and others from the highest part of the rectum run with the superior haemorrhoidal vessels to drain into nodes in the sigmoid mesocolon from which efferent vessels drain into the inferior mesenteric group of pre-aortic nodes.

9. *The bladder.* Lymphatics pass from the bladder to the external, internal and common iliac lymph nodes. From these groups of nodes efferent lymph vessels pass to the lateral aortic (para-aortic) lymph nodes.

10. *The uterus.* Lymphatics from the body of the uterus pass laterally in the broad ligament and run with the ovarian vessels to the lateral (para-) aortic and pre-aortic lymph nodes. From the cervix lymphatics pass to the external and internal iliac lymph nodes and to the common iliac nodes posteriorly.

11. *The vagina.* Lymphatics pass from the vagina to the external and internal iliac and sacral nodes. Below the hymen lymphatics pass, with those of the *vulva*, to the inguinal nodes in the groin.

12. *The ovary and testis.* Lymph from these organs passes to the abdominal aortic nodes.

Pathological Considerations

Bacteria may be arrested in lymph nodes and produce enlargement of them. This may subside, but if the node is destroyed an abscess will form. Tuberculosis of lymph nodes often heals with the deposition of calcium which renders them visible in a radiograph. Malignant cells may be arrested in lymph nodes and they may grow in the node and produce a secondary growth or metastasis.

Superficial lymphatics may become inflamed and they may be seen as red streaks or bands running from a wound to the regional nodes; the latter are likely to be tender and swollen.

Primary tumours of lymph nodes are usually growths of the reticulo-endothelial elements which they contain.

THE RETICULO-ENDOTHELIAL SYSTEM

This term is applied to collections of connective tissue-type cells which are found in the spleen, liver, bone marrow, lymph nodes and in the blood itself where they are known as the large mononuclear cells. Most of them are capable of detaching themselves from the tissues which in their resting state they help to form. They are all highly phagocytic and form part of the defences of the body against infection.

Other functions of this system are the removal of worn out red blood cells by the spleen, the conversion of haemoglobin into bile pigments by the liver and the storage of cholesterol.

THE SPLEEN

The spleen is situated in the left hypochondrium between the fundus of the stomach and the diaphragm. It is about 1 inch (2.5 centimetres) thick, 3 inches (7.5 centimetres) wide and 5 inches (12.5 centimetres) long. It consists of lymphatic tissue, blood spaces and splenic pulp which contains much reticulo-endothelial tissue.

The spleen is in contact with the diaphragm on its convex surface which faces backwards, upwards and laterally. Its medial surface is in contact with the kidney posteriorly, the splenic flexure of the colon inferiorly, the stomach anteriorly and in the middle of the medial surface near the hilum, where the vessels enter and leave the organ, it is in contact with the tail of the pancreas.

Functions of the Spleen

This organ is not essential to life; it is not infrequently removed after rupture resulting from crush injuries and no ill effects necessarily follow.

1. In virtue of the reticulo-endothelial tissue which it contains one function of the spleen is to destroy worn-out red blood cells. From the destroyed cells the iron liberated is stored partly in the

spleen and partly in the liver and in the latter organ the pigment of the haemoglobin is converted into bile pigment.

2. The lymphatic tissue is concerned with the manufacture of lymphocytes.

3. In embryonic life the spleen also produces red blood cells.

4. In view of the enlargement of the spleen which occurs in typhoid fever, malaria etc. it is assumed that it makes antibodies.

5. The spleen is a spongy organ and can store blood. When a

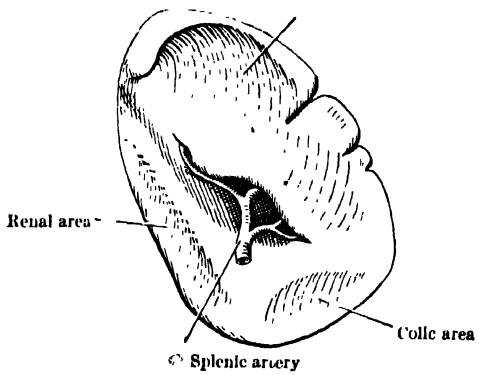


Fig. 12.6 The visceral surface of the spleen.

sudden demand for blood is made it contracts and drives much of the blood it contains into the circulation.

BONE MARROW

The bone marrow is found in the spaces between the trabeculae of the bones. It is met with in two forms, the yellow and the red.

The red marrow is very vascular and is the site of manufacture of the blood corpuscles. It is widespread in the newly born child, but during childhood it is gradually replaced by yellow marrow which is largely composed of fat. By the age of 20 the red marrow exists principally in the vertebrae and in the flat bones such as the ribs, skull, sternum, scapulae and pelvis.

There are parent endothelial cells in the red marrow from which the primitive red blood cell (erythroblast), the primitive platelet (megakaryoblast) and the primitive white blood cell (myeloblast) are formed. In addition some lymphocytes are manufactured in the bone marrow and the primitive lymphocyte (lymphoblast) also develops from the parent cell in the bone marrow.

Pathological Considerations

The reticulo-endothelial system is liable to neoplastic changes and the tumours formed tend to be of widespread distribution. Innocent tumours are very rare but malignant ones such as Hodgkin's disease and lymphosarcoma are not very uncommon.

The reticulo-endothelial cells of the bone marrow may undergo malignant transition causing diseases such as leukaemia and multiple myelomatosis.

13

The Alimentary System

I

THE ALIMENTARY CANAL

The alimentary canal consists of the mouth, the pharynx, the oesophagus, the stomach, the small and large intestines and certain accessory structures such as the salivary glands, the liver, the biliary apparatus and the pancreas.

THE MOUTH AND TONGUE

The mouth extends from the lips and cheeks anteriorly to the anterior pillars of the fauces posteriorly. These pillars are the folds of mucous membrane which run from the soft palate to the tongue. The mouth is divided into the *mouth proper* which contains the tongue and the *vestibule*. The latter is a recess between the cheeks externally and the teeth and alveolar processes internally. On each side the ducts of the *parotid salivary glands* open into the vestibule at the summit of a small papilla opposite the second upper molar tooth. The mouth is lined by mucous membrane which is moistened by mucus and saliva.

The roof of the mouth is formed by the hard palate in front and the muscular soft palate behind; from the posterior margin of the latter the *uvula* hangs down in the midline.

The floor of the mouth is principally formed by the tongue but anteriorly it is composed of muscles. Anterior to the root of the tongue and on either side of the midline are two small papillae on which are the orifices of the ducts of the *submandibular salivary glands*. Close to the opening of each of these ducts are a number of small orifices through which the *sublingual salivary glands* discharge their secretions.

The *tongue* is a muscular organ attached to the hyoid, the styloid process of the temporal bone and the mandible. It consists of an anterior or oral part and a posterior or pharyngeal part; these have

different origins and a different superficial nerve supply but both are composed of muscle bundles running longitudinally, transversely and vertically. On the upper surface a V-shaped furrow separates the anterior from the posterior part. The mucous membrane of the

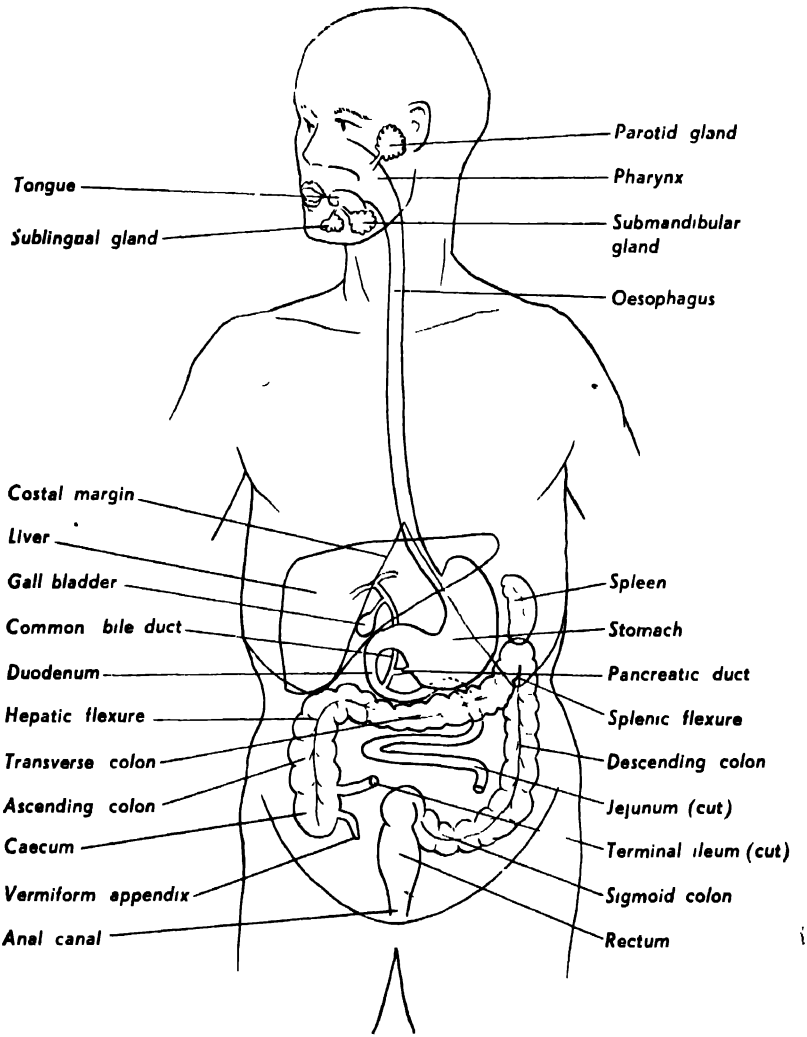


Fig. 13.1 Diagram showing the parts of the digestive system.

anterior part is modified for the special function of tasting food and bears numerous elevations known as *papillae* which contain the end-organs for the sensation of taste, the *taste buds* (p. 263). The pointed

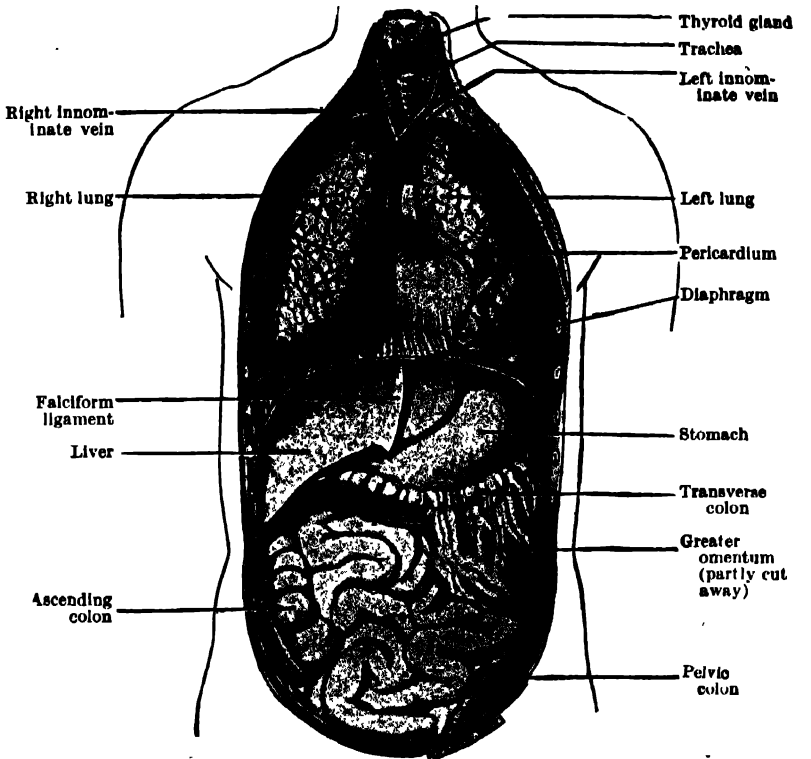


Fig. 13.2 The thoracic and abdominal contents exposed by removal of the anterior wall of the trunk.

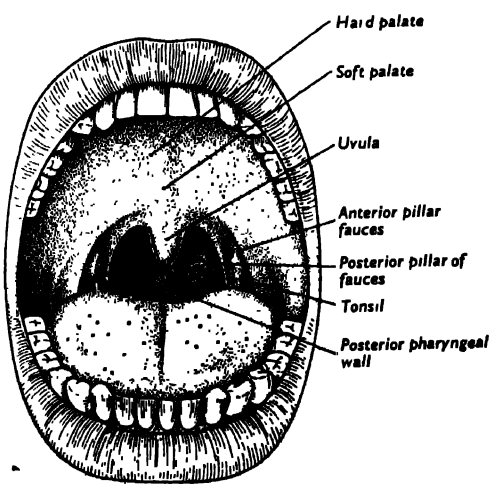


Fig. 13.3 The mouth.

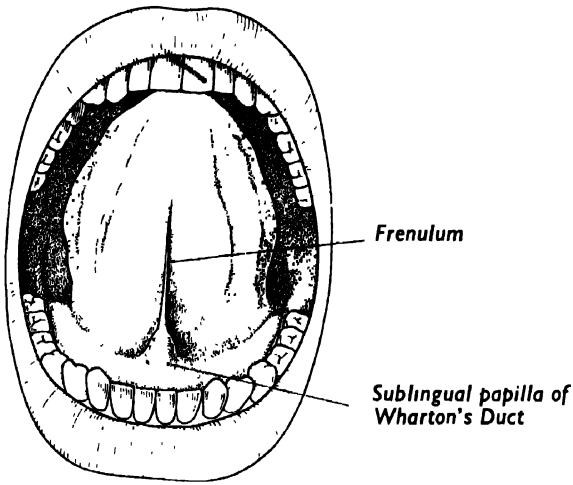


Fig. 13.4 The floor of the mouth and the inferior surface of the tongue.

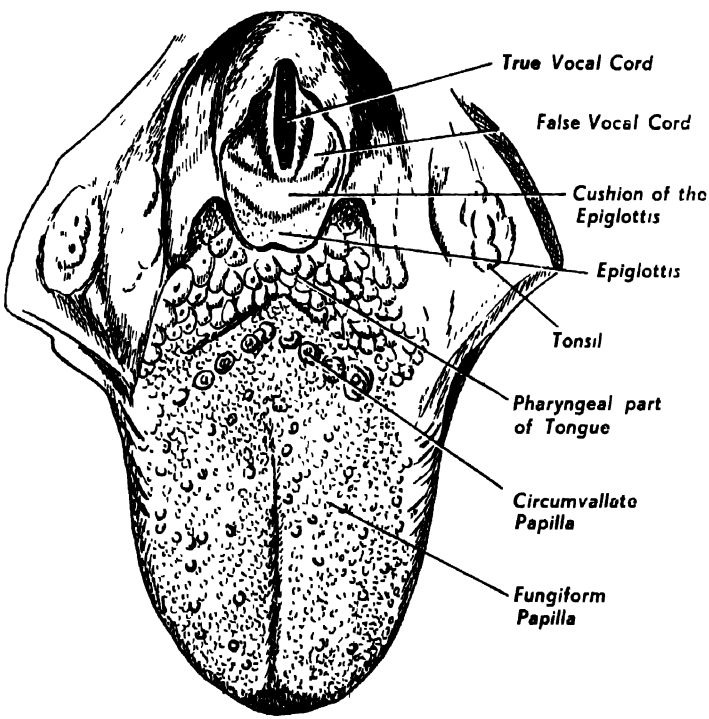


Fig. 13.5 The dorsum of the tongue and the opening of the larynx.

filiform and the flattened fungiform papillae are distributed over the dorsum, sides and tip of the anterior part of the tongue. The largest papillae, the circumvallate, of which there are about twelve, lie just anterior to the V-shaped groove separating the anterior from the posterior parts of the tongue.

The posterior part of the tongue contains lymphoid tissue known as the *lingual tonsil.*

In addition to being the organ of taste the tongue is also of importance in speech, mastication and swallowing.

The tongue is innervated by certain cranial nerves and receives a profuse blood supply from the two lingual arteries each of which is a branch of the external carotid artery of the same side. The lymphatic drainage has already been considered on page 163.

THE TEETH

The teeth are set in sockets in the alveolar processes of the jaws. There are two sets, the *temporary or milk dentition* which erupts during the first two and a half years and the *permanent dentition* which replaces the milk teeth between the sixth and twelfth years. The last teeth of the permanent set, the wisdom teeth, usually erupt in early adult life although they sometimes remain unerupted.

The *temporary dentition* consists of four incisor (or cutting), two canine (or tearing) and four molar (or grinding) teeth in each jaw. There are thus twenty teeth in the complete set.

The *permanent dentition* consists of four incisor, two canine, four premolar and six molar teeth in each jaw. There are thus thirty-two teeth in the complete set. This dentition differs from the first in having premolar and third molar or wisdom teeth.

	molar	premol.	can.	inc.	inc.	can.	premol.	molar	
Temporary dentition									
upper	2	0	1	2	2	1	0	2	= 20
lower	2	0	1	2	2	1	0	2	
Permanent dentition									
upper	3	2	1	2	2	1	2	3	= 32
lower	3	2	1	2	2	1	2	3	

The arrangement of the teeth in the permanent dentition can be described by the *dental formula* in which the teeth of each half of the jaw are numbered consecutively from the first incisor, which is called

number 1, to the third molar, which is called number 8. A full dentition in the left upper jaw would be expressed thus:

$$\frac{|}{12345678}$$

and in a request for a radiograph of the upper right posterior premolar tooth the tooth in question will be indicated thus:

$\underline{5}|$ and for the left lower lateral incisor thus $|\overline{2}$.

That part of the tooth which projects beyond the gum is called the *crown*; the *root* is embedded in the alveolus and is separated from the crown by the *neck*. The root is enclosed in a substance called *cement* which is bound to the socket by the *periodontal membrane* as the

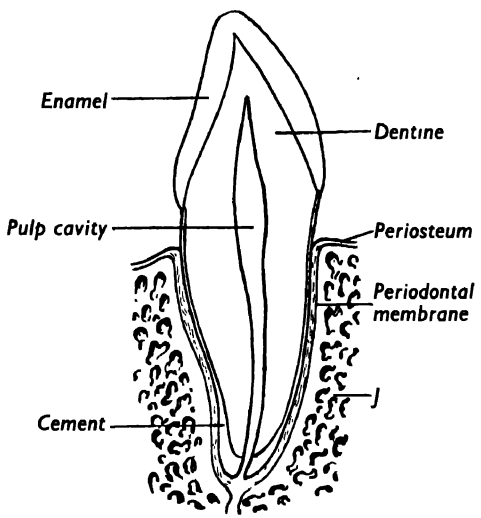


Fig. 13.6 A vertical section of a tooth.

periosteum of the alveolus is called. The cortical bone of the socket is called the *lamina dura* and is usually easily identified in a radiograph. The crown is covered by a dense white substance called *enamel* and the bulk of the tooth is made up of a modified form of bone called *dentine*. Within the tooth is a cavity called the *pulp cavity* which contains blood vessels and nerves.

The incisors and canine teeth have roots which consist of a single fang but the premolars have two fangs and are sometimes called the bicuspid teeth; the molars have three fangs and are also called the tricuspid teeth.

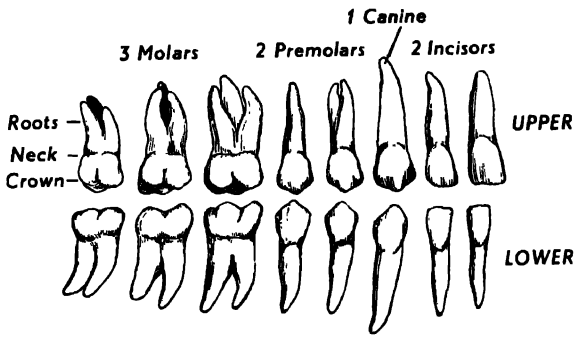


Fig. 13.7 Shapes of human teeth.

THE SALIVARY GLANDS

There are three pairs of salivary glands and they secrete the digestive juice of the mouth, the saliva. They are named the parotid, the submandibular and the sublingual and their secretions are carried to the mouth by ducts.

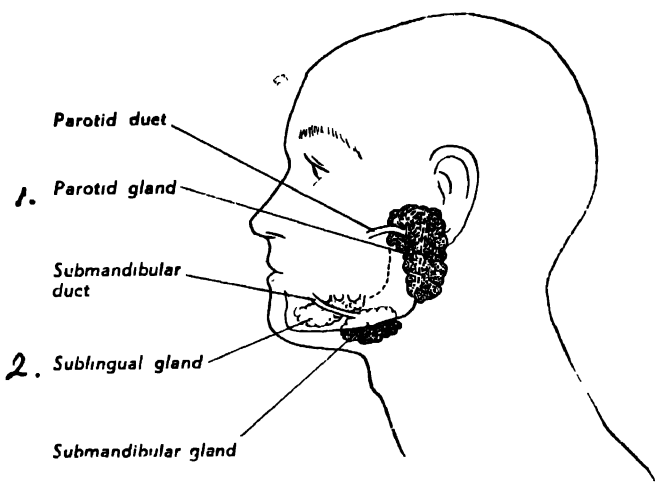


Fig. 13.8 Diagram illustrating positions of the salivary glands of the left side. *Note* the deep part of the submandibular gland and the sublingual gland are less heavily shaded.

The *parotid gland* is the largest and it lies below the external auditory meatus between the ascending ramus of the mandible and the mastoid process. A superficial part of the gland extends round the posterior border of the ramus and lies lateral to the angle of the

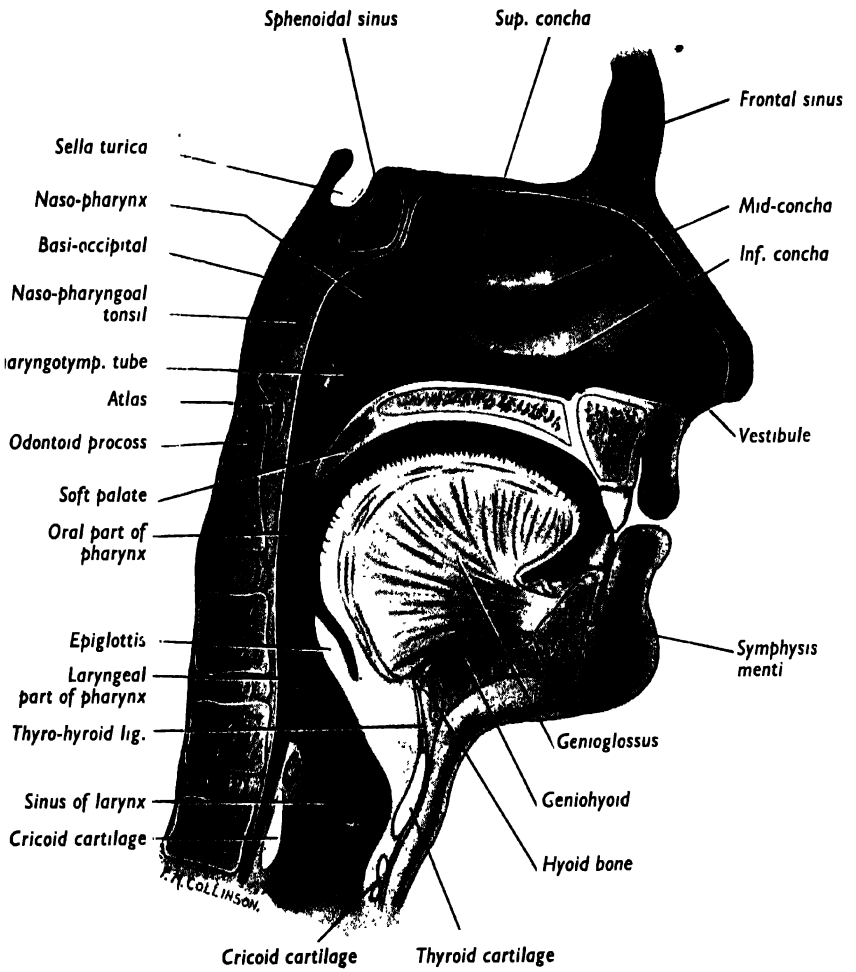


Fig. 13.9 Median section of the nasal cavity, mouth and pharynx.

mandible. The duct (Stenson's) is 2 inches (5 centimetres) long and runs forward from the superficial portion of the gland through the cheek to enter the mouth at the apex of a small papilla opposite the second upper molar tooth.

The *submandibular gland* lies on the deep surface of the posterior part of the body of the mandible and its duct (Wharton's) runs to



Fig. 13.10 (*a*) Radiograph of the neck in the lateral projection showing the soft tissues.

the floor of the mouth to end at the summit of a small papilla beside the *frenulum* (see Fig. 13.4) of the tongue.

The *sublingual gland* is situated beneath the mucous membrane of the anterior part of the floor of the mouth and discharges its secretions directly into the mouth through several small ducts which open in the vicinity of the orifice of the submandibular duct.

Saliva is an alkaline fluid containing the enzyme *ptyalin* in addition to mucin and water. The action of saliva is to moisten the food and lubricate it during swallowing, and the particular function of ptyalin is to convert starch, which is a carbohydrate occurring in bread, potatoes and certain other vegetable foods, into glucose. Ptyalin can only act on cooked starch, for uncooked starch grains are protected by a cellulose covering. Food does not linger long enough in the mouth for much starch to be digested but the process continues in the stomach until the gastric acid has become mixed with the swallowed food and has neutralized the alkalinity of the saliva.

THE PHARYNX

The pharynx lies behind the nasal cavities, the mouth and the larynx. It is a muscular and membranous tube in front of the upper four cervical vertebrae extending from the base of the skull to the cricoid cartilage where it becomes continuous with the oesophagus. It is divided into three portions, the nasopharynx, the oropharynx and the laryngopharynx.

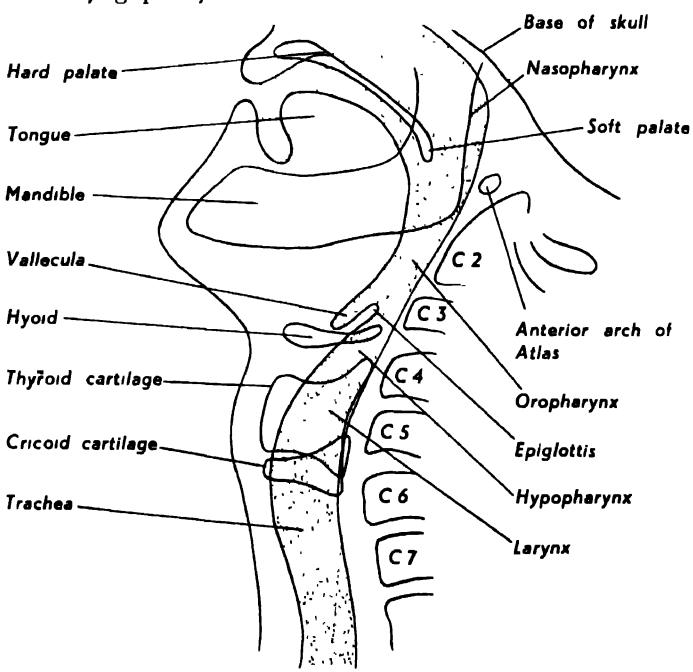


Fig. 13.10 (*b*) Diagram indicating the structures shown in (*a*).

The *nasopharynx* is part of the respiratory tract and was described on p. 145.

The *oropharynx* extends from the level of the soft palate to the epiglottis below. It lies behind the mouth and is separated from it by the anterior pillars of the fauces. On the lateral wall of this part of the pharynx are the posterior pillars of the fauces, and between the anterior and posterior pillars on each side are the *pharyngeal tonsils*. These are the tonsils which are liable to infection and are frequently removed surgically.

The *laryngopharynx* extends from the upper border of the epiglottis to the lower border of the cricoid cartilage; it connects the oropharynx to the oesophagus and lies principally behind the laryngeal cartilages, although it also extends on either side of the upper part of the larynx where it constitutes the *pyriform fossae* (sing. fossa).

The Appearances seen in the Lateral Soft Tissue Radiograph of the Neck (Figs. 13.10*a* and *b*)

Part of the base of the skull, the mandible, the hyoid and the cervical vertebrae are seen. In front of the spine is a shadow caused by the prevertebral soft tissues and the posterior wall of the pharynx. The air-containing nasopharynx, oropharynx, hypopharynx and trachea are shown as shadows of low density. The epiglottis projects upwards from the larynx and is separated by the *vallecula* from the tongue which casts a conspicuous shadow in the mouth. The cricoid and thyroid cartilages may be sufficiently calcified to cast shadows and sometimes calcification is also present in the tracheal rings. In front of the trachea a soft tissue opacity produced by the pretracheal muscles and the isthmus of the thyroid gland may also be seen

THE OESOPHAGUS

The oesophagus is a muscular tube about 10 inches (25 centimetres) long extending from the pharynx to the cardiac orifice of the stomach. It consists of an outer fibrous coat, longitudinal and circular muscle coats and mucous membrane. It starts at the level of the cricoid cartilage opposite the sixth cervical vertebra and has cervical, thoracic and abdominal parts.

Relations of the cervical part of the oesophagus. This portion runs between the trachea which lies in front and the vertebral column behind. The common carotid arteries and the posterior parts of the lateral lobes of the thyroid gland are on either side.

Relations of the thoracic part of the oesophagus. The oesophagus runs through the superior mediastinum, in front of the thoracic duct and vertebral column and behind the trachea. It then passes into the posterior mediastinum where it continues to lie in front of the thoracic duct and vertebral column and just above the diaphragm, which it pierces at the level of the tenth thoracic vertebra, it passes in front of the descending thoracic aorta. The oesophagus runs through the posterior mediastinum on the right of the descending

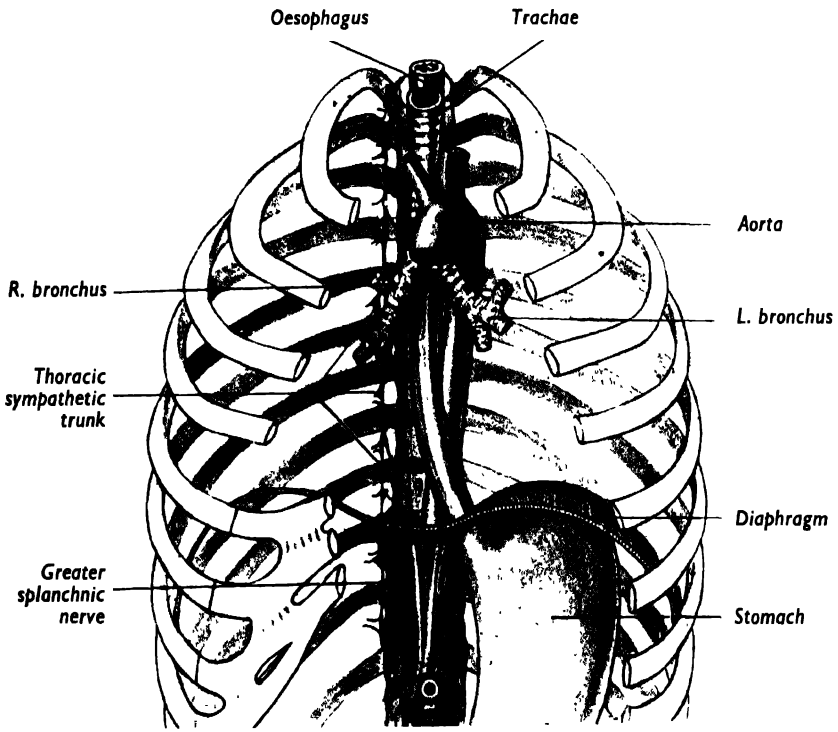


Fig. 13.11 The thoracic portions of the trachea, the oesophagus and the aorta.

aorta to which it is loosely attached; it lies behind the right pulmonary artery and the left main bronchus and below these it is behind the pericardium and left atrium. On the right side are the azygos vein and the right pleura; on the left are the aortic arch, the descending aorta and the left pleura.

Relations of the abdominal part of the oesophagus. This part is only $\frac{3}{4}$ of an inch (2 centimetres) long and it is related anteriorly to the liver.

Structure of the oesophagus. The oesophagus consists from without

inwards, of fibrous, longitudinal and circular muscular coats, a submucous layer and, innermost, the mucous membrane consisting of stratified epithelium.

The Radiographic Appearances of the Oesophagus

In the right anterior oblique position the swallowing of barium cream will demonstrate the oesophagus throughout its length. The narrowest parts of the structure are seen to be at its commencement, at the level of the bronchial impression, and at the lower end. The impression on the anterior wall due to the aortic arch will be seen, below this is the impression caused by the right pulmonary artery and left main brochus, and still further down is the long smooth impression caused by the pericardium and left atrium.

THE ABDOMEN

The abdomen consists of the abdominal cavity proper and the pelvic cavity. The first of these extends from the pelvic brim below to the diaphragm above; it is bounded anteriorly and laterally by the abdominal muscles, lower ribs and iliac bones and posteriorly by

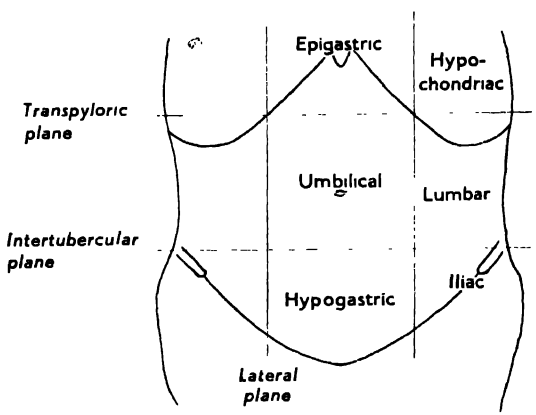


Fig. 13.12 The regions of the abdomen.

the posterior abdominal muscles and lumbar vertebrae. It is lined by peritoneum and contains the stomach, the small and large intestines, the liver, the pancreas, the gall-bladder, the kidneys, the spleen, the suprarenal glands and the great vessels of the abdomen.

The pelvic cavity is bounded by the hip bones and sacrum and contains the lower part of the large intestine, the bladder and, in the female, the genital organs.

The surface markings of the abdomen are dealt with on page 268 *et sqq.*

THE ABDOMINAL REGIONS

Certain regions of the abdomen are named for descriptive purposes. The boundaries of these regions consist of two lateral lines drawn through the midpoint between the anterior superior iliac spine and the symphysis pubis on each side; and two horizontal

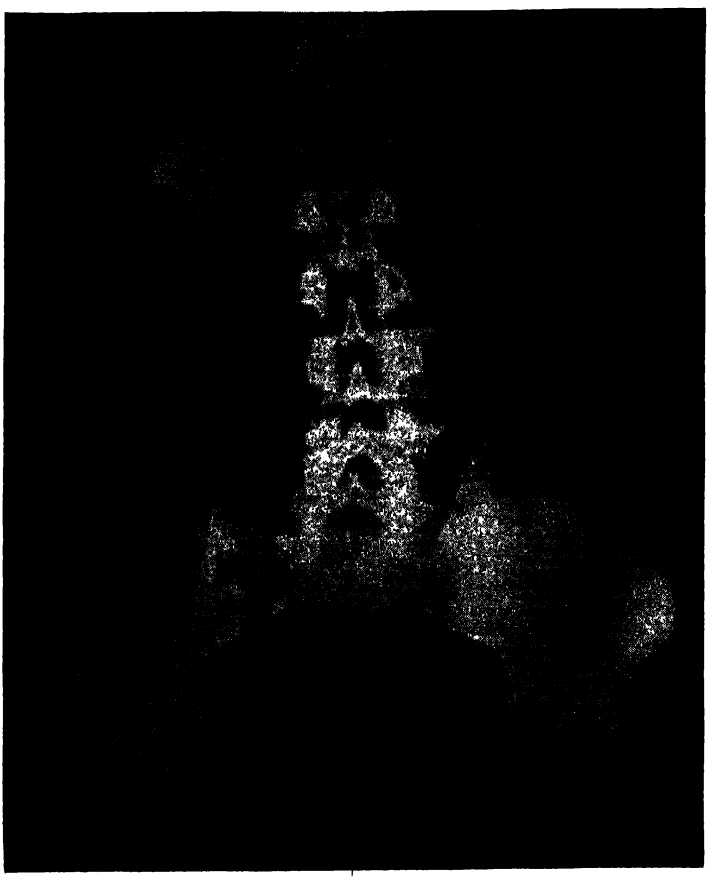


Fig. 13.13 (*a*) Radiograph of structures seen in the posterior projection of the abdomen without the use of contrast media. (*Note* this subject has six lumbar vertebrae. The more usual arrangement is illustrated in Fig. 14.6.)

lines, one of which, the *transpyloric plane*,* is approximately midway between the xiphisternal joint and the umbilicus, and the other, the *intertubercular plane*, is drawn between the tubercles on the outer parts of the iliac crests. These lines demarcate nine regions; the upper row consists of the right and left *hypochondriac* with the *epigastric* separating them, the next row consists of the two *lumbar* regions separated by the *umbilical* and in the lowest row are the *iliac* regions with the *hypogastric* between them. (The hypochondriac, epigastric and hypogastric regions may also be called the hypochondrium, the epigastrium and the hypogastrium respectively.)

Radiographic Appearances of the Abdomen without the use of Contrast Media

The posterior projection in the supine position shows the diaphragm, the lower ribs and the intercostal spaces in the upper part

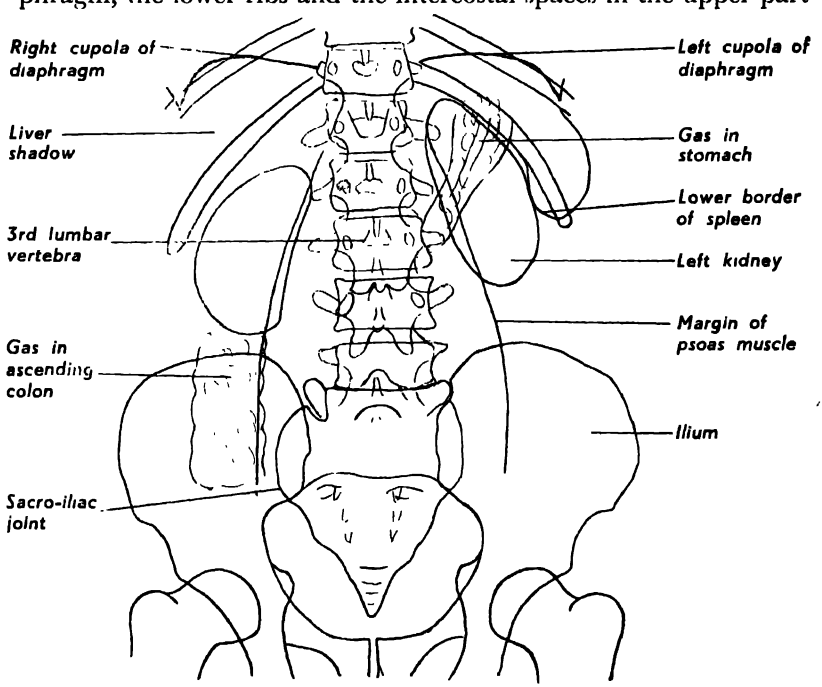


Fig. 13.13 (*b*) Line drawing of (*a*).

* Some authorities do not use the transpyloric plane for separating the two upper rows but employ the subcostal plane which passes through the 10th costal cartilages. The former plane is of much greater practical value and there is no need for the student to burden his memory with the subcostal plane.

of the radiograph and the sacro-iliac joints, the pelvic bones and the pelvic cavity in the lower part. Running down the middle of the radiograph are the lower thoracic and lumbar vertebrae and the sacrum; on either side the lateral borders of the psoas muscle cast shadows which pass downwards and laterally from the twelfth thoracic vertebra.

The uniform opacity in the upper abdomen is caused by the liver. The shadow of the spleen may be seen in the left ninth and tenth interspaces and the kidneys are usually clearly visible because they are surrounded by a transradiant line produced by the perirenal fat (p. 210). Some gas may be seen in the stomach and intestines and faecal material also may be seen in the large bowel. The bladder, if it contains sufficient urine, will cast a shadow in the pelvis.

THE PERITONEUM

The peritoneum is a serous membrane like the pleura. It is thin and slightly moist and it covers many abdominal organs either partially or completely. It enables the organs which it covers to move without friction and it holds some in position by forming ligaments and mesenteries. A curtain-like fold of peritoneum, the *greater omentum*, has a protective function, for its free border may become adherent to an inflamed or injured surface and thus it may prevent contamination of the peritoneal cavity. The greater omentum is often heavily laden with fat and constitutes one of the fat stores of the body.

It is difficult to understand the relationship which exists between the abdominal viscera and the peritoneum without a knowledge of embryology. However, if the abdominal cavity is first imagined to be empty and simply lined with peritoneum – the *parietal peritoneum*, then the various organs must be pictured developing on the *posterior* abdominal wall. Some of these will have peritoneum only on their anterior surfaces and they are said to be *retroperitoneal*; others may bulge into the cavity pushing up the peritoneal covering on the posterior abdominal wall so that they are covered on their fronts and sides by it. Others will push their way so far into the cavity that they drag the peritoneum off the posterior abdominal wall as a double fold in which are their blood vessels, nerves and lymphatics. This is what much of the bowel does so that it is *intraperitoneal*, being covered by the *visceral layer* of peritoneum and suspended from the posterior abdominal wall by a structure known as the *mesentery*. This arrange-

ment is greatly complicated by the enormous increase in length which the small intestine undergoes so that the mesentery by which it is suspended is fan-shaped and measures about 5 inches (12 centimetres) long at its base on the posterior abdominal wall but about 20 feet (6 metres) in length at its attachment to the bowel.

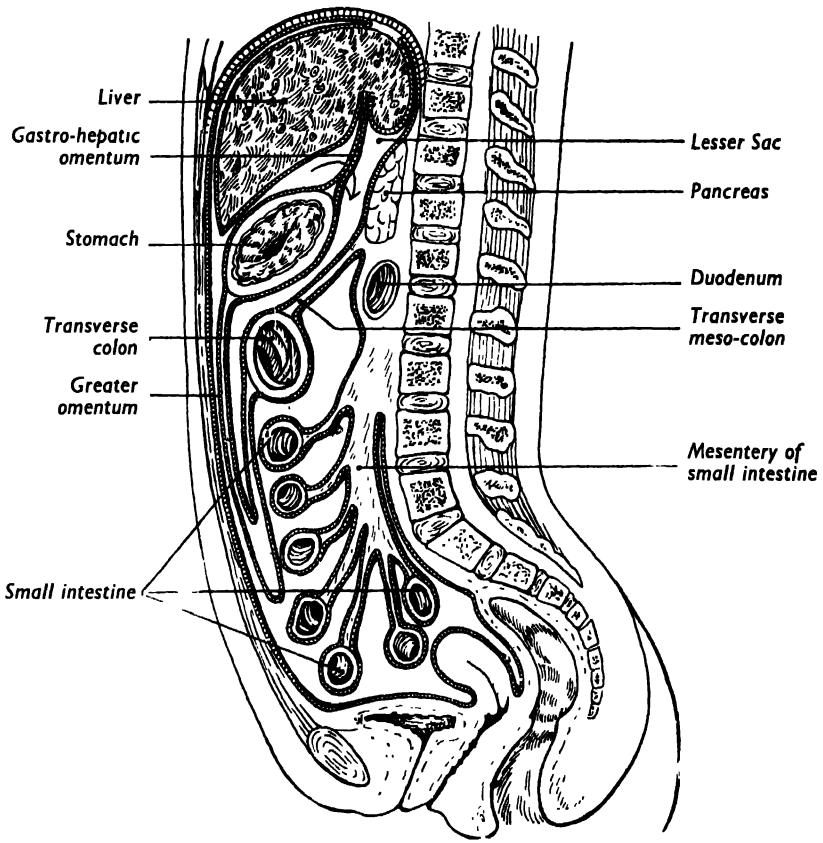


Fig. 13.14 Diagram of a sagittal section of the abdomen to show the disposition of the peritoneum.

The stomach and first part of the duodenum are suspended by the *lesser omentum* and the greater omentum hangs down from the greater curvature of the stomach.

In the pelvis the parietal peritoneum covers the front of the rectum and passes forwards, in the male, to the posterior surface of

the bladder; in the female it covers the anterior and posterior walls of the uterus also. Between the rectum and the uterus is a recess known as the *recto-uterine pouch* (or the Pouch of Douglas).

The peritoneal cavity in the male is a completely closed space but in the female it communicates with the exterior through the uterine tubes (p. 224) which open into it.

THE STOMACH

The stomach is the most distensible portion of the alimentary tract and transmits food from the oesophagus to the duodenum. It varies greatly in size, form and position in different people and in the same individual at different times of the day. It is the most distensible portion of the digestive tract, is J-shaped and lies in the left hypochondriac, epigastric and umbilical regions.

The stomach consists of a dome-shaped upper part, the *fundus*, which is usually filled by the 'gas bubble' in the erect position. The *cardiac orifice* is the upper opening into the stomach and the oesophagus enters through it. The upper border is called the *lesser curvature* and the lower border to which the greater omentum is attached is called the *greater curvature*. About two-thirds of the way down the lesser curvature is the *angular notch* and this divides the *body* of the stomach from the *pyloric portion*, which is subdivided into the *pyloric antrum* and the *pyloric canal*. The *pyloric sphincter*, a thick ring of circular muscle, surrounds the pyloric canal and controls the passage of gastric contents into the duodenum.

Relations of the stomach. The left lobe of the liver and the abdominal

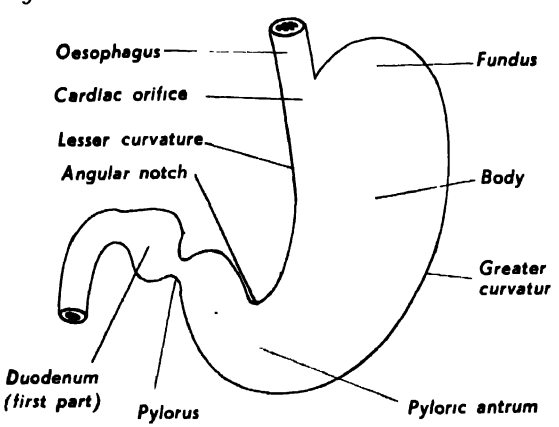


Fig. 13.15 Diagram illustrating the parts of the stomach.

wall are in front of the stomach, and the structures of the 'stomach bed' which include the spleen, the left suprarenal gland, the left kidney and the pancreas lie behind it.

Structure of the stomach. The stomach consists of an outer peritoneal coat, a muscular coat consisting of longitudinal, transverse and oblique layers in this order from without inwards, a submucous coat and a mucous membrane thrown into folds known as *rugae*.

The Functions of the Stomach

The stomach acts as a reservoir for food and it secretes *hydrochloric acid* and certain enzymes. The salivary enzyme ptyalin continues to act until the acid has permeated the swallowed food. The enzymes secreted by the stomach include (1) *pepsin* which in the presence of acid turns proteins into peptones, and (2) *rennin* which curdles milk; the protein of the curd is then digested by the pepsin in the same way as other protein food.

The secretion of gastric juice results from psychic stimuli, such as the sight and smell of food and direct stimuli, such as the presence of food in the organ.

Another function of the stomach has already been mentioned (p. 141) namely, the formation of the 'intrinsic factor' which with the 'extrinsic factor' in the food is elaborated into the anti-anaemic factor by the liver.

THE SMALL INTESTINE

The small intestine extends from the pylorus of the stomach to the ileocaecal valve where it joins the large intestine. It is about 20 feet (6 metres) long and is divided into the duodenum, the jejunum and the ileum.

The duodenum. This part is about 10 inches (25 centimetres) long and lies on the posterior abdominal wall; for the most part it is retroperitoneal. It is C-shaped, embracing the head of the pancreas in its concavity and is divided into four parts. The first part is horizontal, lying in front of the hepatic artery and common bile duct and it has a short intraperitoneal portion known as the 'cap' which is immediately beyond the pylorus. The second part descends in front of the right kidney and inferior vena cava and at about the middle of its medial wall is the duodenal papilla where the orifices of the common bile duct and pancreatic duct are situated. The third part crosses the midline, while the fourth part ascends to become continuous with the jejunum at the duodenojejunal flexure.

The jejunum and ileum. These portions are intraperitoneal and are suspended from the posterior abdominal wall by the mesentery, in which run their blood vessels, lymphatics and nerves. The jejunum starts at the duodenojejunal flexure and lies mainly in the umbilical region; it is about 8 feet (2.5 metres) long and the ileum with which it is continuous is about twelve feet (3.7 metres) in length.

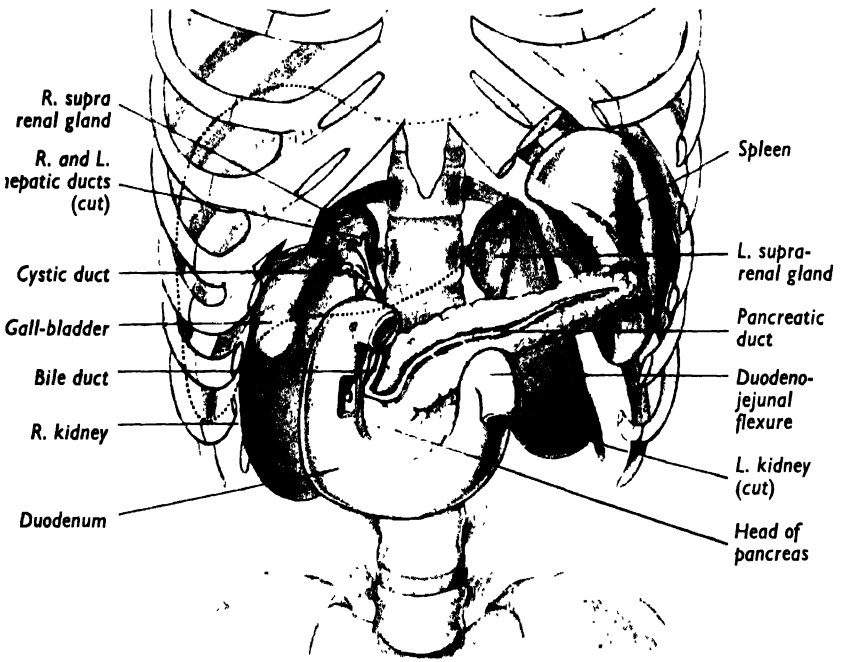


Fig. 13.16 Diagram showing the viscera which lie on the posterior abdominal wall. The dotted outline indicates the position of the liver. The duodenum is cut open to show the common opening of the bile and pancreatic ducts.

Structure of the Small Intestine

The small intestine consists of an outer peritoneal coat, a muscular coat made up of longitudinal and circular layers, a submucous and a mucous coat. The innermost layer of the mucous coat is the mucous membrane which is thrown into permanent folds known as the *circular folds* to increase the surface area for food absorption; there are also crinkly corrugations caused by contraction of the *muscularis mucosae* which is a muscular layer in the deeper

part of the mucous coat. In certain conditions of the small bowel these latter contractions may be deficient and their absence can be demonstrated radiographically.

The mucous membrane of the small bowel has a velvety appearance produced by numerous microscopic projections called *villi* which are richly supplied with blood vessels. Their presence results in a very large surface area of the intestinal wall being brought into contact with the contents of the bowel.

In the mucous coat of the lower ileum deep to the mucous membrane there are characteristic collections of lymphoid tissue known as *Peyer's patches* which are of some medical interest as they become inflamed in typhoid fever.

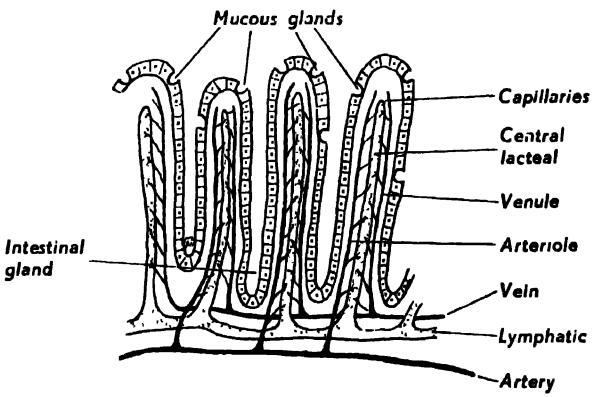


Fig. 13.17 The structure of villi.

Functions of the Small Intestine

The upper part of the small intestine is mainly digestive in function and the lower part is principally concerned with absorption. Food in the process of digestion is called *chyme* and it enters the duodenum from the stomach at frequent intervals after the taking of a meal.

The contents of the duodenum are rendered alkaline by the *bile* and this alkalinity is necessary for the action of the three pancreatic enzymes which enter the duodenum from the pancreas. These enzymes are *trypsin* which digests protein, *amylase*, which digests uncooked as well as cooked starch and *lipase*, which breaks fats up into fatty acids and glycerine. The trypsin is a more potent protein

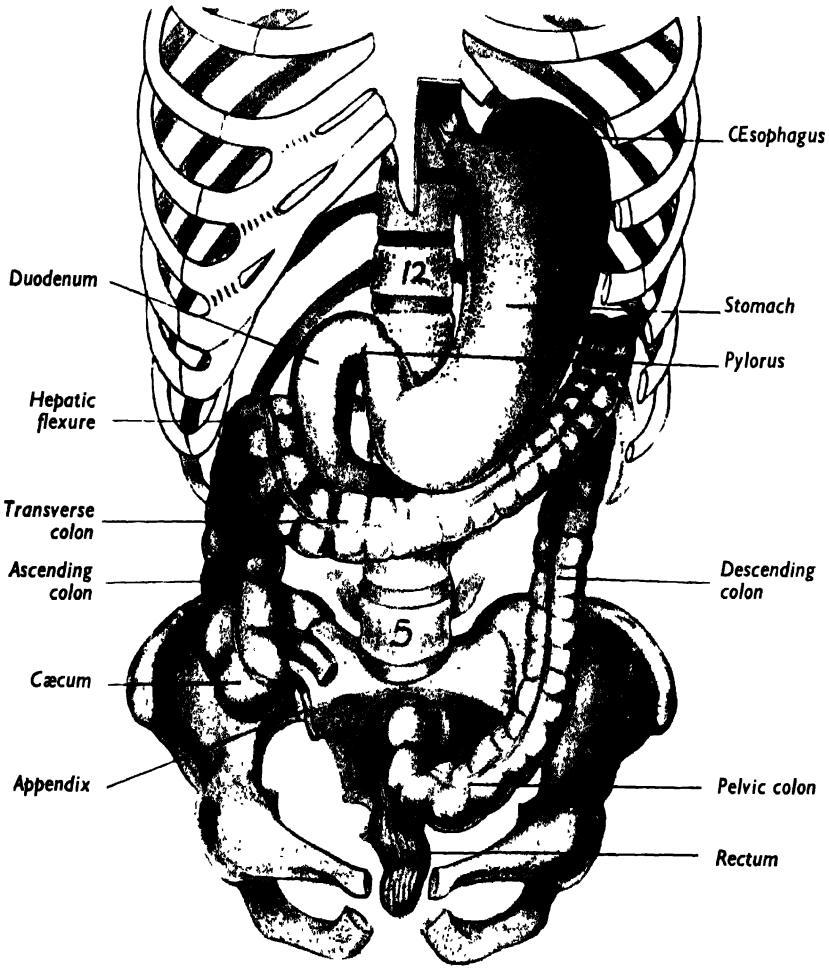


Fig. 13.18 The stomach and large intestine.

splitting enzyme than pepsin for it acts on peptones and turns them into substances called polypeptides.

The digestion of starch, protein and fats is taken further in the jejunum where enzymes are secreted by the intestinal wall in a fluid called the *succus entericus*.

The digestive juices are powerful substances and the reader may wonder why it is that they do not destroy the walls of the organs in which they are produced. It is thought that, in addition to the mucus which the walls of the alimentary canal produce, they also secrete 'anti-enzymes' which counteract the effects of the enzymes in their immediate vicinity. It is a well-known fact that the juices will digest skin and muscle of the abdominal wall if they leak out through, for example, a pancreatic fistula.

The absorption of the products of digestion occurs chiefly in the small intestine although water, salts and glucose are absorbed from the stomach and large intestine also. Glucose results principally from the digestion of carbohydrates; polypeptides and amino-acids result from protein digestion. These substances and water with mineral salts in solution enter the capillaries of the villi and pass via the mesenteric veins to the portal system (p. 138). Fatty acids and glycerol resulting from the digestion of fat take a different route, for they enter the lymphatics (the *lacteals*) of the villi giving the lymph, which is now called *chyle* (p. 159), a milky appearance. The chyle passes to the cisterna chyli whence it goes via the thoracic duct to the left subclavian vein where it enters the blood stream and is carried round the body. The products of fat digestion are deposited in the fat stores of the body (the subcutaneous tissues, etc.) as saturated fats. When the fat stores are required for the production of energy desaturation (the removal of some hydrogen) must take place in the liver, to and from which they are carried by the blood stream.

THE LARGE INTESTINE

The large bowel extends from the ileocaecal junction to the anus; it is about 5 feet (1.5 metres) long and consists of the caecum and vermiform appendix, the ascending, the transverse, the descending and pelvic parts of the colon and the rectum and anal canal.

The **caecum** is a dilated pouch-like structure into which the ileum opens through the slit-like *ileocaecal valve*. It is covered by peritoneum and from it the *vermiform appendix* projects in a variety of positions. The appendix is a worm-like structure, as its name indicates, about 4 inches (10 centimetres) in length, it ends blindly and is possessed of

a small mesentery. It is lined by mucous membrane which is continuous with that of the caecum and it contains lymphoid tissue in its walls.

The **ascending colon** lies in the right lumbar region running upwards from the caecum to the under surface of the liver where it becomes the transverse colon at the *hepatic flexure* which lies in the right hypochondrium. The ascending colon lies behind the peritoneum being covered by peritoneum only on its anterior surface.

The **transverse colon,** which extends from the *hepatic* to the *splenic flexures*, has a mesentery called the *transverse mesocolon* and is variable in position. It curves downwards as it crosses the abdomen and then ascends to the splenic flexure which lies near the spleen in the left hypochondium.

The **descending colon** runs downwards from the splenic flexure, through the left lumbar region and left iliac fossa to join the pelvic colon at the pelvic inlet. Like the ascending colon it is clothed by peritoneum on its anterior surface and so is constant in position.

The **pelvic (or sigmoid) colon** is of variable length in different individuals. Because it has a mesentery, called the *pelvic mesocolon*, it is of variable position but it lies mainly in the cavity of the pelvis.

The **rectum** is continuous with the pelvic colon and is about 5 inches (12.5 centimetres) long. It lies in the pelvis in front of the lower part of the sacrum and coccyx; it is intraperitoneal in its upper part but extraperitoneal below. It is curved from side to side as well as antero-posteriorly. The lower part of the rectum is expanded and is called the ampullary portion. In front of the upper part of the rectum coils of ileum lie in the lower part of the peritoneal cavity; below this the rectum is related in the female to the uterus and vagina and in the male to the bladder and prostate gland.

The **anal canal** is the terminal 1 inch (2.5 centimetres) of the large intestine and is surrounded by the anal sphincters.

Structure of the large intestine. The large intestine may be considered as consisting of three layers. The outermost consists of connective tissue and peritoneum, which, in the ascending and descending colon, is incomplete. Next comes the muscular coat which differs from that of the rest of the intestine in that the longitudinal muscle is not spread evenly round the circumference of the bowel but is collected into three bands, the *taeniae*, which run from the caecum to the upper part of the rectum. These bands are not as long as the rest of the bowel wall, so they gather it up into sacculations known as haustrations.

The innermost layer is composed of the submucosa of connective

tissue, nerves, vessels and lymphatics and the mucous membrane of columnar epithelium containing many cells which secrete mucus.

Functions of the Large Intestine

This part of the alimentary canal is chiefly concerned with the preparation, storage and evacuation of the indigestible and unabsorbable food residues known as *faeces*. This is accomplished partly

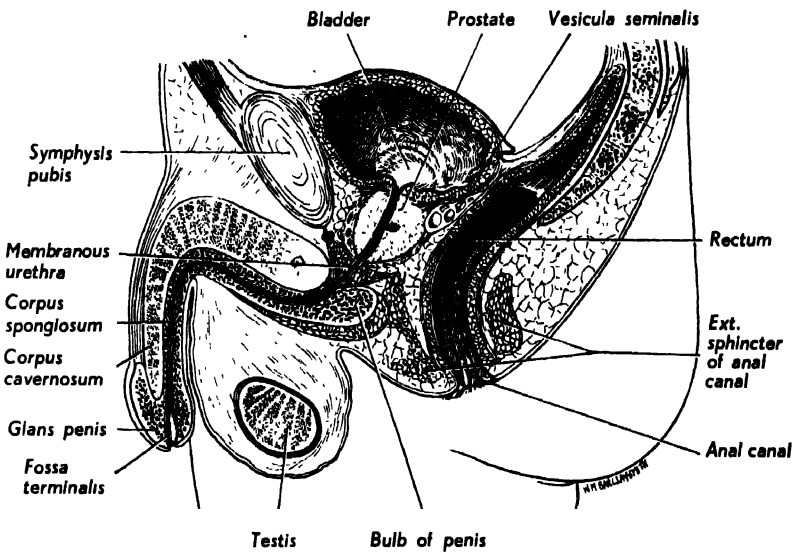


Fig. 13.19 Sagittal section of the male pelvis and external genital organs.

by reducing the bulk of the intestinal contents by the absorption of water and the decomposition of cellulose by the bacteria which are normal residents in the colon. Certain substances may be excreted by the wall of the large intestine into the faeces, for example, the salts of heavy metals such as bismuth and iron. The intestinal wall also secretes mucus which lubricates and protects the mucous membrane.

THE RADIOGRAPHIC APPEARANCES OF THE STOMACH AND INTESTINES

Radiographic Appearances of the Stomach

If a little barium emulsion is massaged over the mucous membrane of the fasting stomach during a barium meal examination the rugal folds will be seen. When the stomach is partly filled with the



Fig. 13.20 (*a*) Normal stomach and duodenum immediately after ingesting a barium meal.

emulsion and the subject is in the erect position the gas bubble in the fundus will show above the fluid level at the top of the barium column. The various parts of the stomach such as the greater and lesser curvatures and the body and pyloric portions will be recognized. Peristaltic waves (p. 197) will be seen at fluoroscopy either churning the contents or driving them through the pylorus.

Radiographic Appearances of the Small Intestine

The duodenal cap is seen as a conical structure with its base towards the pylorus. Since this part is intraperitoneal it is mobile and



Fig. 13.20 (*b*) Radiograph following ingestion of a small quantity of barium showing the mucosal pattern of the duodenum and jejunum.

differs in its situation according to whether the patient is erect or recumbent. Barium will pass rapidly through the remaining portions of the duodenum under the influence of peristalsis and the mucosal pattern is seen to be typical of that of the small intestine, it is

produced by a combination of the circular folds and the corrugations caused by contraction of the muscularis mucosae.

Radiographic Appearances of the Large Intestine

The colon may be demonstrated by the administration of 2 to 3 pints (2 litres) of barium sulphate emulsion per rectum. The entire



Fig. 13.20 (*c*) The large intestine demonstrated by a barium enema. The terminal ileum is also shown.

large bowel may be seen in the posterior (A.P.) projection (see Fig. 13.20(*c*)) but oblique views of the sigmoid colon, hepatic and splenic flexures and lateral projections of the rectum may be required. The course of the large bowel can be studied; its calibre is widest at the caecum and rectum and narrowest at the vermiform appendix. The characteristic haustral pattern is seen when the bowel is filled and

after evacuation the length and calibre are diminished but the mucosal pattern is demonstrated.

THE MOVEMENTS OF THE ALIMENTARY TRACT

Deglutition (swallowing)

The act of swallowing is performed after food has been chewed and compressed between the hard palate and the tongue to make a *bolus*. This is passed into the pharynx where the soft palate is drawn towards the posterior wall to prevent the bolus from entering the nasopharynx. As this occurs the larynx is raised and the epiglottis is

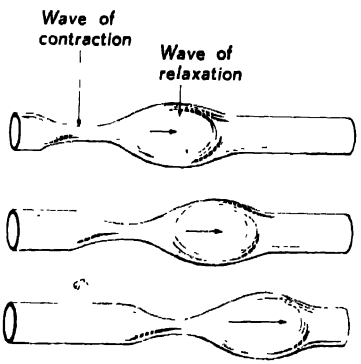


Fig. 13.21 Diagram illustrating a peristaltic wave passing along a short segment of a hollow organ such as the bowel or ureter. The bolus of food (in the bowel) is propelled in the direction indicated by the arrows by a wave of contraction preceded by a wave of relaxation.

deflected to cover the glottis and so prevent the entry of swallowed material into the larynx. When the bolus enters the oesophagus the act of swallowing becomes involuntary and peristaltic waves, aided in the erect position by gravity, carry it down to the stomach.

Peristalsis

This term is used to describe the method by which involuntary muscle propels material along hollow tubes; it consists of a relaxation occurring ahead of the material and a contraction following behind.

Movements of the Stomach

These may be studied during barium meal examinations. The

fasting stomach will be found to be almost empty with its musculature contracted. As it is distended with the opaque material muscular contractions will be observed; initially these do not result in the expulsion of stomach contents but are churning movements which mix the food with the gastric juice. When the pylorus relaxes the stomach will begin to empty and the time taken for this to occur depends on many factors, the most important of which is the nature of the food. Fatty foods and proteins are retained longer than carbohydrates and a heavy rich meal may stay in the stomach for 5 or 6 hours.

Movements of the Small Intestine

Three movements occur in the small intestine, segmentation, pendulum movements and peristalsis. The intestinal contents are churned up by a combination of segmentation and pendulum movements; the former consists of contractions of the circular muscle dividing the lumen into short segments, and the latter are to-and-fro movements. Peristalsis starts in the lower part of the duodenum and by frequent and rapid waves the chyme is propelled into the distal part of the ileum where the bowel is much less active. The entry of food or fluid into the stomach stimulates peristaltic activity in the lower part of the ileum by the gastro-ileal reflex and this results in the passage of the ileal contents into the caecum.

Movements of the Large Intestine

The large intestine does not exhibit continuous activity in the way that the small bowel does, but peristaltic movements occur at intervals especially after taking food as a result of what is called the **gastrocolic reflex**. The contents of the large intestine are called **faeces** and these are mainly stored in the descending and sigmoid parts of the colon. It is probable that the rectum is usually empty and it is the arrival of faeces in the rectum which gives rise to a desire to defaecate.

Defaecation

The expulsion of faeces requires the relaxation of the anal sphincter, the contraction of the rectum and certain accessory muscles in the pelvis, and the assistance of a general increase in abdominal pressure brought about by contraction of the diaphragm and holding the breath.

*THE LIVER**

The liver is a large organ weighing over 3 lb. (1.5 kilogrammes). It is irregular in shape but can be likened to a wedge with its base to the right and its apex to the left. It lies principally in the right hypochondrium but stretches across the epigastrium to reach the left hypochondriac region. It is divided into two main lobes, a large right lobe and a smaller left (see Fig. 13.2). The surface anatomy of the liver is described on p. 270.

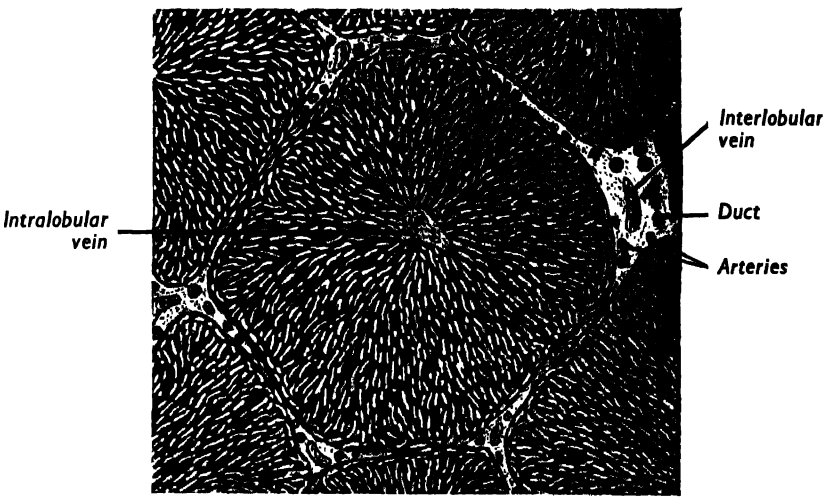


Fig. 13.22 Minute structure of the liver.

Relations of the Liver

The *upper surface* is related to the under surface of the diaphragm; the *anterior surface* is related to the under surface of the diaphragm and the adjoining part of the anterior abdominal wall. The *posterior surface* of the liver is related to the diaphragm, the inferior vena cava, the abdominal aorta and the oesophagus. The hepatic veins leave the posterior surface to enter the adjacent inferior vena cava. The *inferior surface* slopes upwards and backwards from the anterior margin and is related, on the right, to the gall-bladder, the hepatic flexure of the colon, the right suprarenal gland and right kidney and, on the left, to the fundus of the stomach.

* Before studying the liver the student is advised to revise the portal venous system (page 138).

. The *portal fissure* (or the porta hepatis) is an opening on the under surface through which the right and left hepatic ducts, the portal vein and the hepatic artery pass.

The peritoneum covers most of the organ but is lacking over its upper surface (the bare area of the liver) where it is reflected to become continuous with that on the under surface of the diaphragm.

Structure of the Liver

The liver is spongy in consistency and is enclosed within a thin fibrous capsule. It is made up of many lobules between which are tributaries of the bile ducts and the interlobular (inter = between) branches of the hepatic artery and portal vein. In the centre of each lobule is the intralobular (intra = within) vein, a tributary of the hepatic veins.

The structure of the liver can be related to its functions for the cells of the lobules are arranged in columns between which are blood spaces known as the *sinusoids* and both portal venous blood (containing the products of digestion) and arterial blood mix in them. The blood percolates through the lobule to reach the intralobular vein whilst the bile which is made by the cells of which the lobule is composed flows in the opposite direction to reach the interlobular tributaries of the hepatic bile ducts.

It will be appreciated that the liver has a dual supply of blood – oxygenated blood from the hepatic artery which arises from the coeliac axis, a branch of the aorta, and portal venous blood from the portal vein. The blood leaves the liver by flowing from the intralobular veins into the hepatic veins which drain directly into the inferior vena cava which is in contact with the posterior surface of the liver.

Functions of the Liver

The liver may be compared with a chemical laboratory where many complicated processes are occurring simultaneously. Some of these functions are concerned with the conversion of absorbed foodstuffs into substances required by the body for metabolism, some are concerned with the storage and manufacture of material and some with the detoxication of poisons and the excretion of various substances. A few of these functions will be briefly dealt with.

The formation of bile. This is a continuous process between one and two pints of bile being formed by the liver cells daily. It is excreted into the tributaries of the hepatic ducts and passed to the

gall-bladder and duodenum. Bile contains pigments derived from haemoglobin and substances known as bile salts.

The formation of urea. The end-products of protein metabolism result in the formation of nitrogen residues which are converted into urea by the liver and excreted by the kidney.

Storage. Vitamins A and D, iron, the anti-anaemic factor (pp. 141, 187) and glycogen (derived from glucose) are amongst the substances stored by the liver.

The production of heat. The chemical processes result in many cases in the production of heat which plays an important part in the maintenance of body temperature.

THE BILIARY APPARATUS

The biliary apparatus consists of the ducts through which the bile is transported and the gall-bladder which concentrates it.

The *bile ducts* start as the interlobular bile capillaries in the liver, which unite with vessels of increasing size and converge on the porta hepatis to form the *common hepatic duct.* One and a half inches (3 centimetres) below this the common hepatic duct unites with the

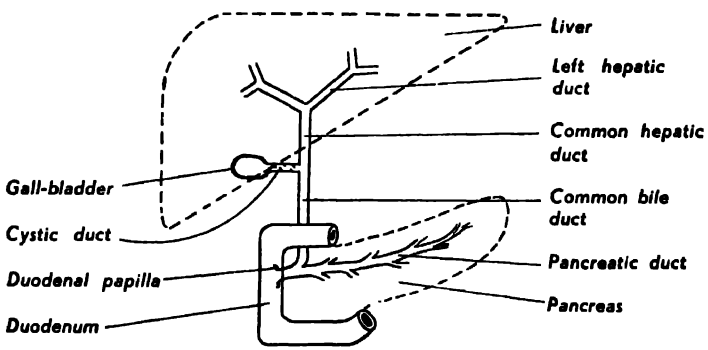


Fig. 13.23 Diagram illustrating the biliary apparatus.

cystic duct from the gall-bladder to form the *common bile duct.* This duct passes behind the first part of the duodenum and the head of the pancreas closely related to the hepatic artery and the portal vein. It then turns laterally to enter the duodenum at the summit of the duodenal papilla; the pancreatic duct may open into its lower end or both ducts may open separately on the dudoenal papilla.

The *gall-bladder* is a pear-shaped organ measuring 3 to 4 inches (7 to 10 centimetres) in length and having a capacity of about one

ounce (30 to 50 cubic centimetres). It is attached to the under side of the liver and its blind end, the fundus, extends below the lower margin of the liver in contact with the inner aspect of the anterior abdominal wall at the level of the tip of the ninth costal cartilage when the patient is supine. The cystic duct leaves the neck of the gall-bladder. The duct is about $1\frac{1}{2}$ inches (3.5 centimetres) long and joins the common bile duct about $2\frac{1}{2}$ inches (7 centimetres) above its lower end.

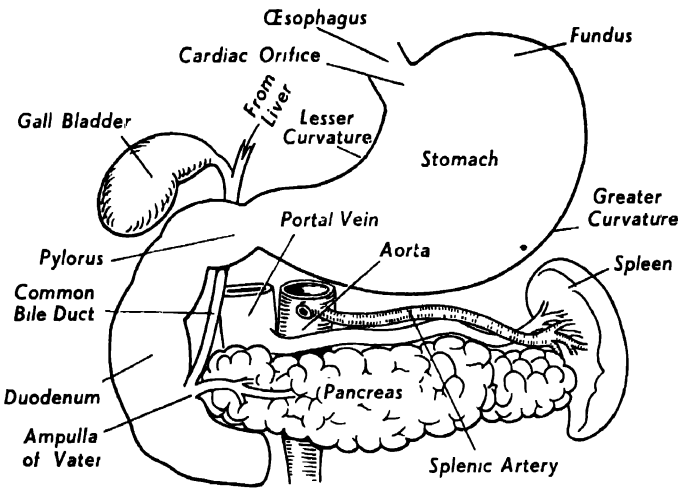


Fig. 13.24 The stomach, pancreas and bile ducts, etc.

Structure of the biliary tract. The gall-bladder consists of an outer peritoneal coat, a fibromuscular coat and, innermost, a mucous membrane of columnar epithelium.

The bile ducts lack a peritoneal coat. They have a fibromuscular coat and mucous membrane. The mucous membrane of the cystic duct possesses a spiral fold, called the spiral valve, which is sometimes visible at cholecystography.

Function of the biliary tract. The function of the gall-bladder is to concentrate and store bile and, under the stimulus of fatty food, to contract and expel it into the duodenum. The function of the bile ducts is to convey bile from the liver into and out of the gall-bladder and to the duodenum. Thus bile passes in both directions through the cystic duct. It will pass from the common hepatic duct into the gall-bladder to be concentrated and when the gall-bladder contracts it will be expelled back along the cystic duct and the common bile duct will conduct it to the duodenum.

Functions of Bile

Bile is an aqueous solution of bile salts and pigments and is alkaline in reaction. The salts are necessary for the action of all the pancreatic enzymes, they are important in the absorption of fatty acids and glycerol, both of which are derived from fats, and they exert an aperient action on the large intestine. No known function is performed by the pigments which are responsible for the colour of the faeces.

Radiographic Appearances of the Biliary System

Various iodine containing preparations may be given orally or by injection to demonstrate the biliary system. When it is taken by

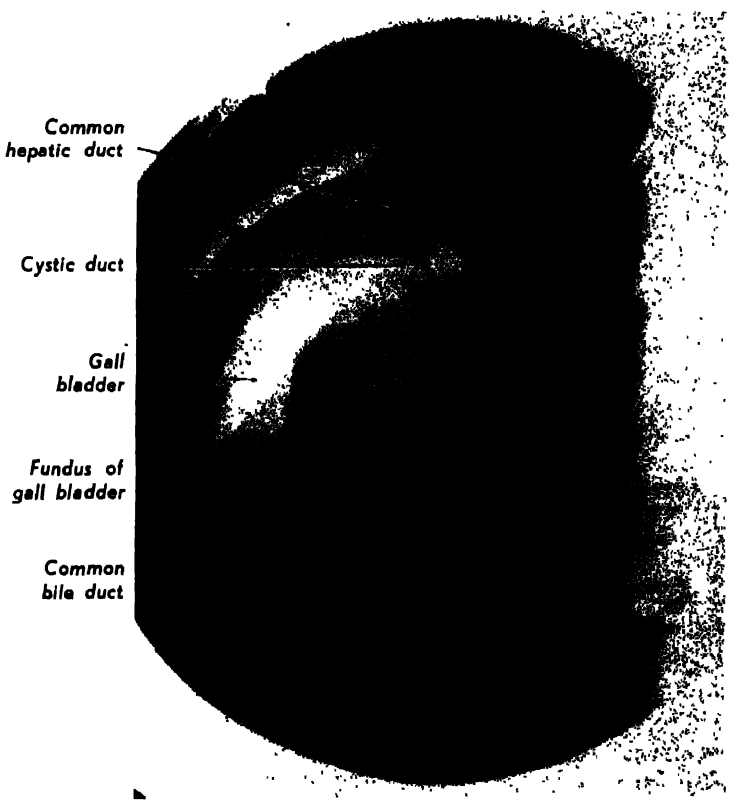


Fig. 13.25 The gall-bladder and bile ducts outlined by telepaque. The radiograph was taken after a fatty meal had caused the gall-bladder to contract.

mouth the opaque medium is absorbed from the small intestine and carried to the liver, which excretes it into the bile. The opaque medium will be concentrated with the bile in the gall-bladder and when concentration is sufficient this structure will be visualized. If a fatty meal is then given the gall-bladder will contract and the cystic and common bile ducts will be rendered visible as the opaque medium travels to the duodenum.

As with other intra-abdominal structures the position of the gall-bladder depends on bodily type, phase of respiration, the state of fullness of other organs and whether the subject is erect or recumbent. The organ is, however, usually described as lying in the angle between the twelfth rib on the right and the upper lumbar vertebrae but owing to the variations in its position the radiograph usually includes the lower two ribs on the right, the lumbar spine and the right iliac crest.

THE PANCREAS

The pancreas lies on the posterior abdominal wall at the level of the first lumbar vertebra. It is retroperitoneal, about 6 inches (15 centimetres) long and consists of a *head*, *neck*, *body*, and *tail*. The head is enclosed on three sides by the duodenal loop and behind it are the portal vein and the common bile duct. The body crosses the inferior vena cava, the aorta, the left suprarenal gland and the upper pole of the left kidney. The tail lies against the hilum of the spleen in front of the left kidney. The pancreas forms part of the 'stomach bed', and the stomach lies anterior to it.

The pancreatic duct starts in the tail of the gland and runs to the right, through the entire length of the gland, to enter the duodenum in company with the common bile duct at the duodenal papilla.

The *structure of the pancreas*. The pancreas is both a secreting gland of the alimentary system whose cells discharge their secretion, pancreatic juice, into the pancreatic duct and it is also a gland of internal secretion for it contains tissue known as the *islets of Langerhans* which secrete *insulin*.

The *functions of the pancreas* are to produce an internal secretion known as insulin which is discharged directly into the blood stream, and an external secretion known as pancreatic juice which is transported to the bowel in the pancreatic duct. These two activities are entirely separate. Insulin is made in parts of the gland known as the islets of Langerhans and plays an essential part in carbohydrate metabolism (see p. 207). The action of pancreatic juice has already been described (see p. 189).

Pathological Considerations

The oesophagus may be narrowed by stricture formation due to scarring or cancer. Failure of relaxation of the lower end is called *achalasia of the cardia or cardiospasm.*

The stomach is frequently affected by *peptic ulceration* and *cancer.*

The duodenal cap is frequently affected by *peptic ulceration* and scarring of the pylorus or duodenal cap resulting from chronic ulceration (*pyloric stenosis*) may interfere with the emptying of the stomach.

The small intestine is rarely affected by cancer but may be *obstructed* by adhesions or by its passage through a hernial orifice, etc.

An abdominal hernia occurs when intra-abdominal contents pass through points of weakness in the abdominal wall by which they are normally confined, for example the femoral and inguinal canals and less commonly the diaphragm. If the structure which herniates (e.g. intestine) has its blood supply constricted it is said to be *strangulated* and it may become gangrenous.

Small outpouchings of the wall of the alimentary canal called *diverticula* may occur, the commonest site for them is the large intestine where they may become inflamed, a condition known as *diverticulitis.*

The colon is a frequent site for the occurrence of cancer. It may also be affected by a distressing complaint called *ulcerative colitis* in which the mucous membrane ulcerates.

The gall-bladder may become inflamed – *cholecystitis*, or it may be the site of stone formation – *cholelithiasis.* Stones may migrate and block the common bile duct resulting in *jaundice*, in which condition the bile pigments accumulate in the blood.

Definitions

Oesophagoscopy, gastroscopy and sigmoidoscopy: the passage of an instrument for the purpose of viewing the interior of the oesophagus, stomach and sigmoid colon respectively.

Gastrostomy, ileostomy and colostomy: the making of an opening of a temporary or permanent nature into the stomach, ileum or colon respectively (-ostomy = making a hole into).

Gastrectomy and colectomy, cholecystectomy: the removal of part or the whole of the stomach, colon or gall-bladder (-ectomy = removal of).

Gastro-enterostomy: the making of an opening between the stomach

and the upper small intestine for the purpose of by-passing the duodenum.

II

NUTRITION AND METABOLISM

FOOD

Food provides the body with material for growth and for replacement of tissue suffering from the effects of wear and tear; it also provides energy for the performance of work.

The essential constitutents of food are water, proteins, fat, carbohydrates, salts and vitamins. The process of assimilating food requires its ingestion, mastication (chewing), digestion and absorption and the elimination of indigestible or unabsorbable material (defaecation). Certain substances such as water, mineral salts and glucose can be absorbed through the intestinal wall unchanged but others require to be digested.

Nearly three-quarters of the body weight is due to water i.e. in an average man there are about 50 litres (110 lb.) or 88 pints of water. About three-quarters of the water of the body exists within the cells of the tissues and the remainder is found in the blood plasma, lymph and tissue fluid. Water plays many roles in the body, and it forms the vehicle in which secretions are dissolved. Many salts are dissolved in it and these play an essential part in many vital processes and render possible osmosis by which fluid and metabolites traverse cell membranes, etc. There is a balance between the intracellular and extracellular fluid which is constant in health and is maintained in large measure by the action of the kidneys in controlling the output of fluid and of certain mineral salts which are responsible for the osmotic pressure of the body fluids. Water is, of course, taken in as fluid or in food and some is formed in the body by chemical reactions; it is eliminated from the body by the kidneys, lungs, skin and bowel.

When the osmotic pressure of the body fluids is disturbed because of kidney disease, intestinal disease, etc. fluid may collect in the tissues (*oedema*) and in the pleural and pericardial spaces and peritoneum producing pleural and pericardial *effusions* and *ascites* respectively.

Digestion is the process of conversion of food into substances which can be absorbed through the intestinal wall. This usually involves the breaking down of large molecules into smaller ones.

Proteins are nitrogenous containing foods such as meat, eggs, cheese etc., and their chief use is in body-building. During digestion proteins are broken down into peptones and amino-acids.

Fats are of animal or vegetable origin and, with carbohydrates, are sources of energy. Animal fats also provide the body with vitamins A and D. During digestion these are broken down into fatty acids and glycerol.

Carbohydrates such as starch and sugars are, like fats, non-nitrogenous foods whose chief function is to provide energy. In the process of digestion they are converted into glucose.

Salts are required for the formation of bone, the production of haemoglobin and the maintenance of the correct chemical composition of the tissue fluids.

Vitamins are complex substances which are required in very small amounts for a variety of essential purposes. The functions of the vitamins are most easily studied by observing the effects of deprivation. Thus lack of vitamin C produces scurvy, lack of Vitamin D produces rickets and lack of vitamin E is one of the causes of sterility.

SUMMARY OF DIGESTION

Site	Secretion	Enzyme	Action
Mouth (page 178)	saliva	ptyalin	starch→glucose
Stomach (page 187)	gastric juice	hyrochloric acid	proteins→peptones
		pepsin	
		rennin	curdles milk
Duodenum (page 189)	bile and pancreatic juice	amylase	starch→glucose
		trypsin	proteins→peptones
		lipase	fats→fatty acids and glycerol
Jejunum (page 189)	succus entericus	erepsin	peptones→amino-acids
		other enzymes	sugars→glucose, etc.

METABOLISM

Metabolism has already (p. 5) been defined as the chemical processes by which food is converted into energy or protoplasm and it has been described as consisting of *anabolism* and *catabolism*. During the period of growth anabolism exceeds catabolism but in an adult in normal health they balance each other and if anabolism exceeds catabolism there will be a tendency to put on weight.

The energy requirements of the body are usually expressed in Calories* and the total requirements of the body vary with the amount of physical exercise the individual takes. Adults require from 2500 (e.g. a housewife or sedentary worker) to 4000 Calories (e.g. a man doing heavy manual work) per day. When the body is at rest, e.g. during sleep, energy is required for vital processes such as the maintenance of body temperature, the beating of the heart, etc. These minimal metabolic requirements are called *basal metabolism*. A normal diet must supply enough energy for basal metabolism as well as for growth, physical exercise, etc., and it should be balanced so that the proportions of protein, fat and carbohydrate are approximately one-sixth, one-sixth and two-thirds respectively. The actual amounts are calculated from a knowledge of the energy value of these constituents of the diet. Thus for every 1 g. of protein or carbohydrate fully oxidized 4 Calories are produced and for every 1 g. of fat fully oxidized the yield is 9 Calories. The rate at which Calories are required for basal metabolism (the *basal metabolic rate*) is under the control of the thyroid gland; it is increased in fever and in cold weather and is relatively higher in childhood. The basal metabolic rate can be measured and it provides a method of investigating the activity of the thyroid gland.

* 1 calorie is the amount of heat required to raise 1 **ml.** of water 1° centigrade. This is a very small unit of heat and in connection with metabolism and dietetics a larger unit is required. Such a unit is the Calorie (large C) which is the amount of heat required to raise 1 **litre** 1° C., i.e. 1 Calorie = 1000 calories.

14

The Urinary System

Waste products are eliminated from the human body by the kidneys, the skin, the lungs and the bowel. The *kidneys* are the secretory glands of the urinary system, the *ureters* convey the *urine* from the kidneys to the *bladder* where it is stored, and from which it is periodically voided by being discharged through the *urethra*.

THE KIDNEYS

The kidneys lie behind the peritoneum on the posterior abdominal wall. Each kidney is 4½ inches (12 centimetres) long, 2 inches (5 centimetres) wide and 1 inch (2.5 centimetres) thick and has a convex lateral surface and a concave medial one. The medial surface contains the *hilum* through which the renal vessels, the lymphatics and the ureter pass and each kidney also has an anterior and a posterior surface and an upper and a lower pole. The hilum lies opposite the first lumbar vertebra and the right kidney usually lies a little lower than the left (see p. 271).

The medial border of the kidney shows a deep recess, the *renal sinus*, into which the hilum leads. The renal sinus contains the *major* and *minor calyces*; the former arise from the upper expanded portion of the ureter called the *pelvis* and the latter arise from the major calyces. About three or four minor calyces usually arise from each major calyx.

At the upper pole of each kidney lies the suprarenal gland. The anterior surface of the right kidney is related to the liver, the duodenum and the hepatic flexure of the colon. On the left side the anterior surface is related, from above downwards, to the stomach, the spleen, the tail of the pancreas, the jejunum and the splenic flexure of the colon.

Structure of the Kidneys

The kidneys are enclosed by a fibrous capsule which is surrounded

by perirenal fat. If the kidney is divided vertically from side to side it will be seen to consist of a reddish-brown outer part, the *cortex*, and a paler inner portion, the *medulla*, which is composed of a series of *pyramids*. The apex of each pyramid projects into a minor calyx

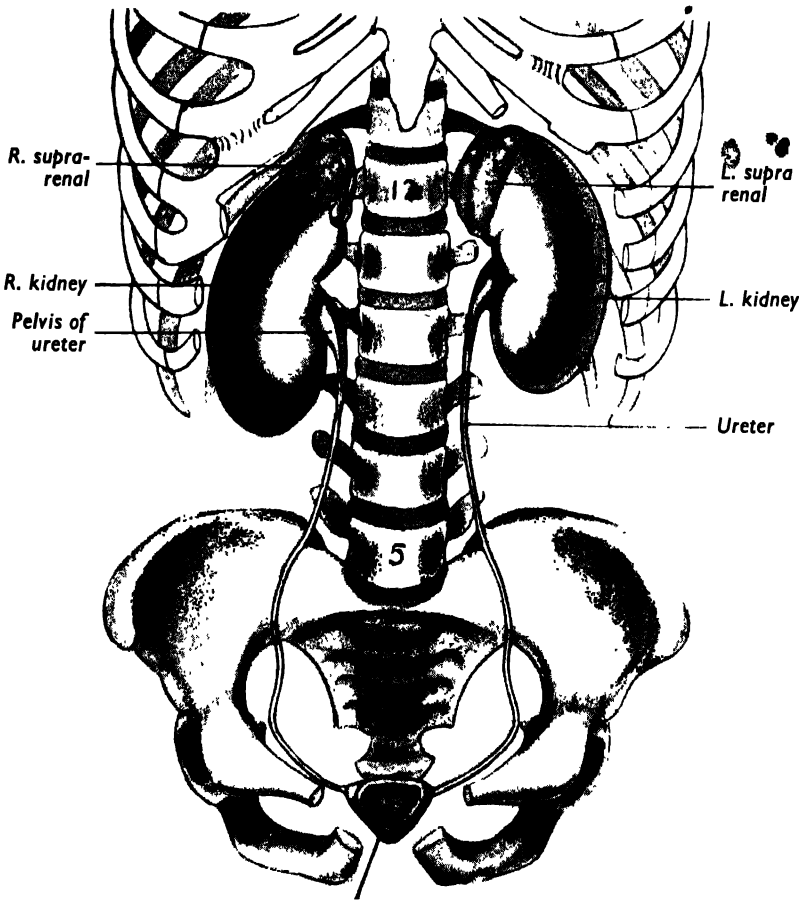


Fig. 14.1 The kidneys, ureters and bladder.

where it produces a prominence called a *papilla* and there are usually from one to three papillae in each minor calyx.

Microscopic examination shows that:

1. The *cortex* consists of large numbers of *renal* (or *Malpighian*) *corpuscles* and the tubules leading from them.

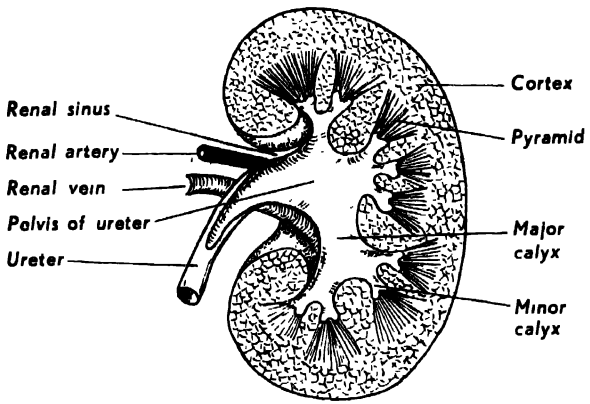


Fig. 14.2 A sagittal section through the kidney.

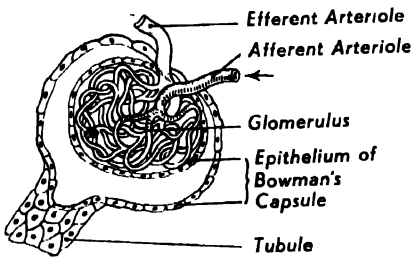


Fig. 14.3 A Malpighian body — highly magnified.

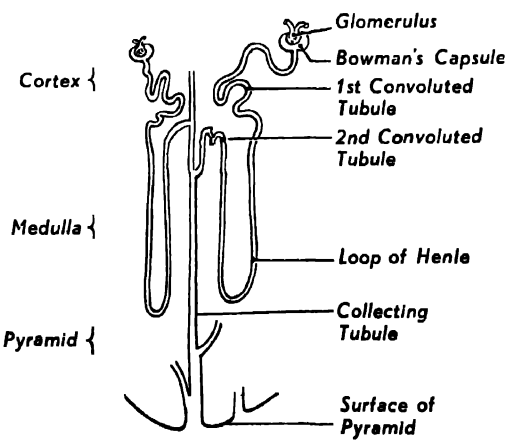


Fig. 14.4 Diagram of a kidney tubule.

The renal corpuscles, which are about 0.2 mm. in diameter, are filters for the extraction of fluid and dissolved material in the blood. They are composed of a central tuft of capillaries, the *glomerulus*, which invaginates an epithelial sac from which the *uriniferous tubule* leads. The tubule takes a winding course before finally joining the collecting tubules in the medulla.

2. The *pyramids* of the medulla are composed of the collecting tubules which drain the urine from the tubules leading from the renal corpuscles. They open into the minor calyces on the surface of the papillae.

The kidneys are supplied with blood by the renal arteries, which are branches of the abdominal aorta and arise at the level of the first lumbar vertebra.

The Ureters

Each kidney is connected to the bladder by a ureter which is a muscular tube about 10 inches (25 centimetres) long. At the upper end is the funnel-shaped *pelvis* of the ureter (or kidney) and below this the ureter consists of abdominal and pelvic portions.

The abdominal portion runs down on the psoas muscle behind the peritoneum and crosses the common iliac vessels to enter the pelvis. The pelvic portion turns medially and reaches the bladder. In the female the lower end of the ureter is close to the cervix of the uterus.

Structure of the ureter. The ureter is principally composed of unstriped muscle. Externally there is a fibrous tissue coat and internally is the mucous membrane which is composed of transitional cell epithelium.

THE URINARY BLADDER

The urinary bladder lies in the pelvic cavity behind the pubes and pubic symphysis. When empty it is compressed by the weight of the abdominal organs above it but as it fills it becomes ovoid in shape. In infancy and childhood, because of the relatively small size of the pelvic cavity, the bladder lies at a higher level.

The bladder is covered above by peritoneum and the superior surface in the male is thus separated from the pelvic colon and ileum, coils of which rest upon it. In the female the superior surface is related to the body of the uterus and the uterovesical pouch of peritoneum.

Below the bladder in the male is the prostate gland and in the

female the muscles of the pelvic floor and urethral sphincter. The inferolateral aspects of the bladder are related to the side walls of the pelvis; posteriorly in the male are the seminal vesicles and the rectum and, in the female, the vagina.

The bladder is a muscular organ lined by mucous membrane; it is capable of containing about ¾ of a pint (400 cubic centimetres) of urine. There are three openings into the bladder, one for each ureter and one for the urethra. The latter is surrounded by the internal sphincter. The triangular area between the urethra and the ureteric orifices is called the *trigone* and the mucous membrane here is always smooth whereas in the rest of the organ in the empty state it is thrown into folds.

The function of the bladder is to store and to expel urine.

The blood supply is derived from the internal iliac (hypogastric) artery.

The lymphatic drainage of the bladder has been dealt with elsewhere (p. 165).

THE URETHRA

The male urethra forms part of the reproductive system as well as being the conduit from the bladder. It is about 7½ inches (19 centimetres) long and is divisible into three parts:

1. *The prostatic urethra.* This is about 1¼ inches (3 centimetres) long and is surrounded by the prostate gland; the ejaculatory ducts open into its floor.

2. *The membranous portion.* This is the shortest portion being about ¾ of an inch (1.75 centimetres) in length and is very frequently damaged in crushing injuries to the pelvis and in falls astride unyielding objects.

3. *The penile portion.* This is about 5 inches (12.5 centimetres) long and is surrounded by the corpus spongiosum (p. 221).

In the female the urethra is about 1½ inches (4 centimetres) in length and lies anterior to the vagina.

Functions of the Kidneys

The kidneys are concerned with:

1. The excretion of water.
2. The excretion of waste products such as urea and uric acid.
3. The control of the alkalinity of the blood.
4. The excretion of drugs, toxins and even bacteria (e.g the kidneys can excrete typhoid bacteria).

The kidneys perform these functions by producing *urine* which consists essentially of water, salts and nitrogenous matter. The water is derived mainly from that taken in by mouth but some is formed as an end-product in the metabolism of protein, fat and carbohydrate.

The nitrogenous constituents of urine such as urea, uric acid, etc., are derived partly from the breakdown by the liver of the amino-acids from the protein of the food and partly from the tissues as a result of catabolism.

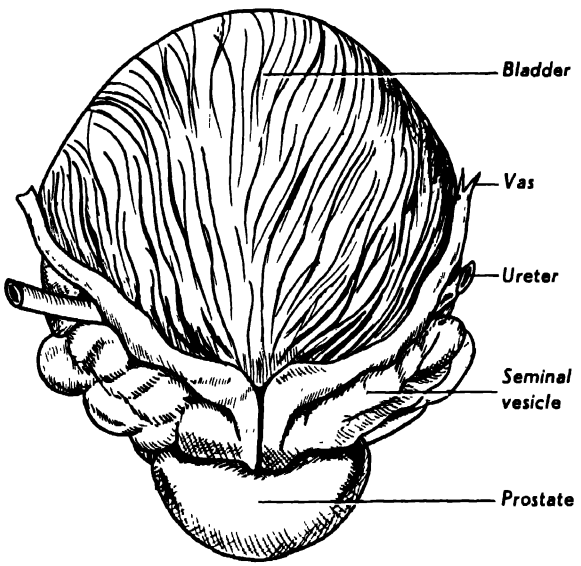


Fig. 14.5 The structures at the base of the male bladder seen from behind.

The kidneys play a large part in regulating the alkalinity of the blood by varying the amount of acids and acid salts they excrete in the urine. They are also of great importance in controlling other chemical constituents of the blood and they do this by excreting the excess when one of them rises above the 'renal threshold'. Below this threshold the substance is conserved in the blood and not excreted by the kidneys.

The Formation of Urine

Urine is formed by filtration through the epithelium covering the glomeruli; this process depends on the blood pressure and on the

osmotic pressure of the blood itself. The filtrate passes from the renal corpuscle into the tubule, becoming concentrated during its passage by the absorption of water from it and receiving certain substances from the blood which are secreted by the cells of the renal tubules. It is then discharged from the collecting tubules into the minor calyces and propelled into the bladder by peristalsis (p. 197) passing through the major calyces, the pelvis and the ureter of each side.

The volume of urine secreted daily depends on the fluid intake and the amount of fluid lost by other routes, such as perspiration and breathing. It is about 2½ pints (2 litres).

Micturition

Urine is stored in the bladder and is voided at intervals by the reflex act (p. 250) of micturition which consists of relaxation of the sphincter of the urethra and contraction of the musculature of the bladder. This reflex is under conscious control after infancy.

The Radiographic Appearances of the Urinary Tract

The urinary tract may be examined by radiography without the use of contrast media (see Fig. 13.13).

Various contrast methods may be employed but it is only proposed to describe the appearances seen when one of these methods, excretion urography, is used. In this examination an aqueous iodine-containing compound is injected intravenously and is excreted and concentrated by the kidneys, thus rendering parts of the urinary tract opaque to X-rays.

Excretion Urography

In addition to the features seen in the radiograph of the abdomen, excretion urography will demonstrate the pelvis of the ureter and the major and minor calyces of each side, the ureters and, when sufficient opaque medium has been excreted, the bladder. The ureters are superimposed on the shadows of the lumbar transverse processes and they are then seen to cross the sacro-iliac joints and to run parallel with and about ¾ of an inch (2 centimetres) from the inner wall of the pelvis. At the level of the ischial spine they turn medially to enter the bladder.

There are three constrictions normally present in the ureter. The first of these is at the upper end of the abdominal portion at its junction with the pelvis (of the ureter), the second is at the level of

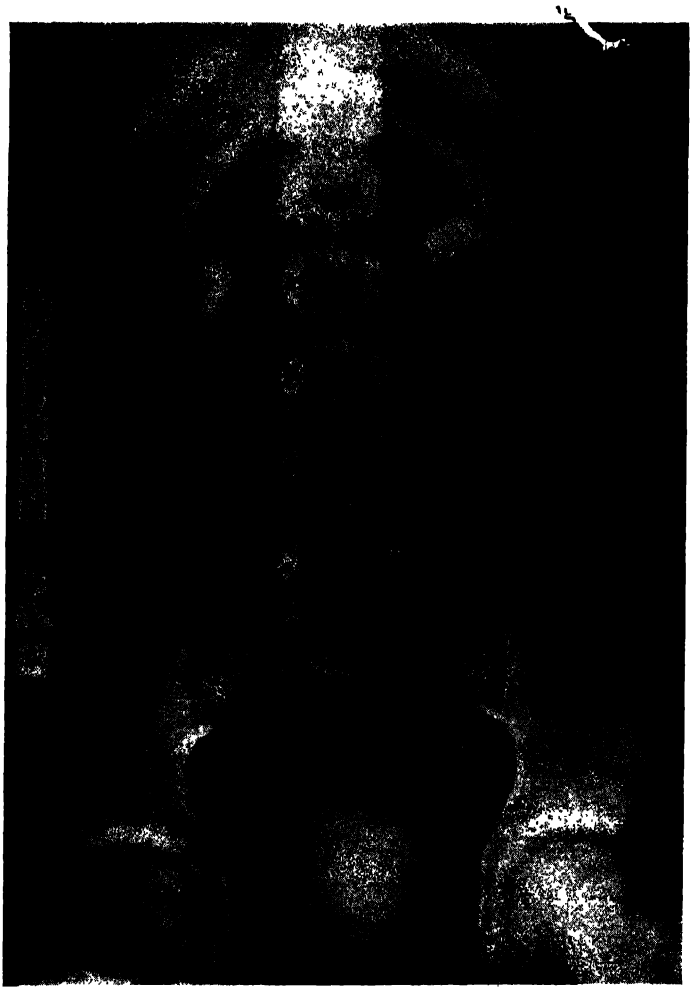


Fig. 14.6 Radiograph of the abdomen of a child with the urinary tract opacified following the injection of an iodine-containing preparation.

the brim of the pelvic cavity and the third is at the junction of the ureter with the bladder. Between these constrictions the ureter widens out forming the two so-called ureteric spindles.

Pathological Considerations

Patients with disorders of the urinary tract frequently complain of one or more of the following symptoms:

Frequency of micturition – often due to infection or prostatic enlargement.
Dysuria – painful micturition.
Haematuria – passage of blood in the urine.
Pyuria – pus in the urine.
Renal or ureteric colic – acute pain often due to the presence of a small stone in the pelvis or ureter.
Incontinence – inability to control the emptying of the bladder often as a result of nervous disease.

Conditions which a radiographer may come across in her work include the following:

Nephritis – an inflammatory condition of the kidneys which may become chronic and be attended by grave consequences.
Uraemia – the accumulation of nitrogenous waste products in the blood usually due to renal failure.
Pyelitis – inflammation of the pelvis and ureter.
Cystitis – inflammation of the bladder.
Hydronephrosis – dilatation of the pelvis and calyces usually due to a partial obstruction to the ureters or urethra.
Stone formation – nephrolithiasis or calculus disease is common in hot climates. Stones which contain calcium are often visible in radiographs.
Cysts may occur in the kidney and if multiple they may be examples of a developmental abnormality called *polycystic kidneys*.
Tumours of the kidney are usually either potentially or actually malignant. The *hypernephroma* is met with in adults and is often responsible for haematuria but Wilm's tumour (nephroblastoma) is the type which affects young children.

15

Reproductive System

MALE GENITAL ORGANS

The male organs of generation are:

1. The two testes.
2. The two epididymes.
3. The two seminal ducts.

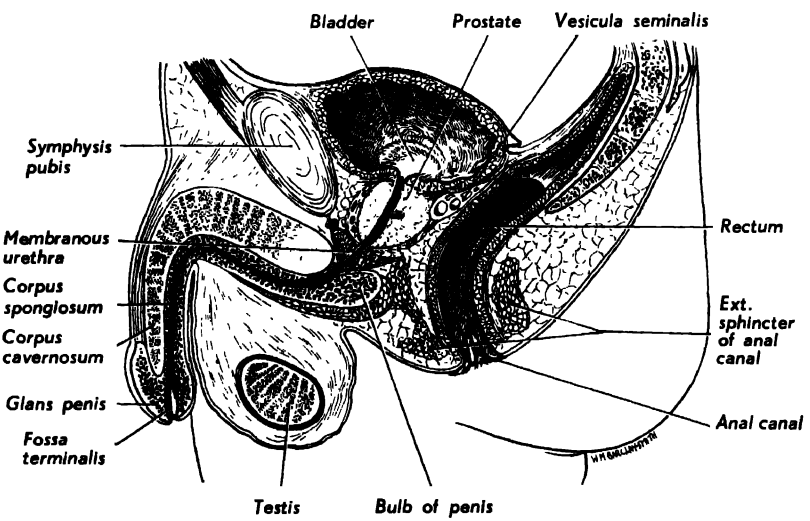


Fig. 15.1 Sagittal section of the male pelvis and external genital organs.

4. The two seminal vesicles.
5. The prostate gland.
6. The penis.

THE TESTES (sing. testis)

The testes are oval in shape and lie on each side of the *scrotum* in which they are suspended by the spermatic cords. They are abdominal organs until the seventh month of intra-uterine life when they pass into the scrotum. They are composed of finely coiled tubules, the *seminiferous tubules*, which are enclosed in a fibrous capsule, the *tunica albuginea*. A double layer of serous membrane called the *tunica vaginalis* separates the testis from the scrotum in the same way as a double layer of pleura separates the lungs from the chest wall. The spermatozoa and the fluid in which they are discharged constitute the seminal fluid or *semen*.

The *function* of the testes is to produce the male sex cells, the spermatozoa (p. 7), and an internal secretion, testosterone, which is responsible for the secondary sexual characteristics.

The *lymphatic drainage* has already been considered (page 165).

THE SCROTUM

This is a pouch composed of muscle and skin and is divided into two compartments in which the testes lie.

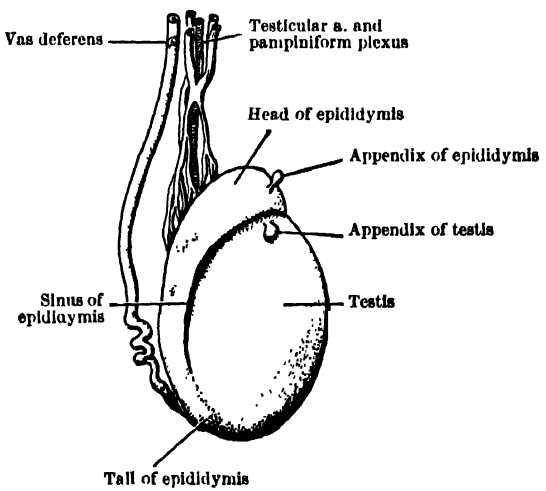


Fig. 15.2 The right testis and epididymis viewed from the external aspect. The vas deferens has been separated from the other constituents of the spermatic cord.

THE EPIDIDYMES (sing. epididymis)

These are two crescent-shaped structures, each lies on the posterolateral aspect of the testis and is composed of a tortuous tube about

18 feet in length when unravelled. They transmit the seminal fluid from the testes to the seminal ducts.

THE SEMINAL DUCTS (Vasa deferentia, sing. vas deferens)

The seminal ducts begin at the lower poles of the epididymes and run with the spermatic cords through the inguinal canals into the pelvis. They join the ducts of the seminal vesicles to form the ejaculatory ducts which open into the prostatic urethra.

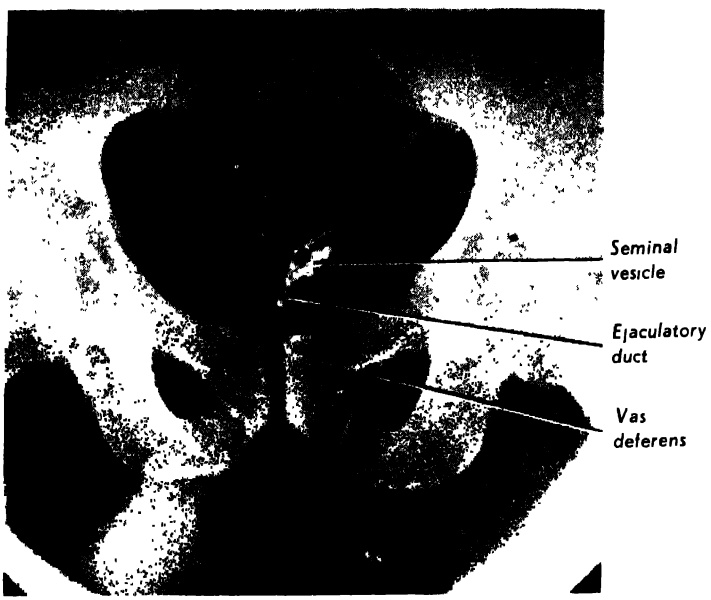


Fig. 15.3 A demonstration of the left ejaculatory duct, seminal vesicle and part of the vas deferens (seminal duct). The course of the vas within the scrotum is not, of course, shown.

THE SPERMATIC CORDS

Each consists of the extra-abdominal part of the vas deferens, the testicular artery, a plexus of veins, the testicular lymphatics, a muscle known as the cremaster which helps to suspend the testis and fibrous coverings derived from the abdominal wall.

THE SEMINAL VESICLES (See Fig. 14.5)

These glands lie on the posteroinferior aspect of the bladder and their secretions are discharged via the ejaculatory ducts into the prostatic urethra (p. 213).

THE PROSTATE GLAND

This is a single midline structure usually described as being chestnut-shaped and it surrounds the upper part of the urethra (Fig. 15.1) lying immediately distal to the base of the bladder. It produces a secretion which, like that of the seminal vesicles, is mixed with the seminal fluid in the prostatic urethra.

THE PENIS

This is the organ by which the semen is deposited in the female genital tract and it is attached at its base to the ischium and pubis. It is composed of three erectile structures, the two *corpora cavernosa* and the *corpus spongiosum* which become rigid and erect when engorged with blood. The urethra traverses the corpus spongiosum and opens externally on the *glans*, as the slightly enlarged distal portion of the penis is called. The *prepuce* or foreskin is a sheath of skin which partially covers the glans.

FEMALE GENITAL ORGANS

The female organs of generation are:

(*a*) *Internal organs*
1. The two ovaries.
2. The uterus.
3. The two uterine (Fallopian) tubes.
4. The vagina.

(*b*) *External organs*
1. The vulva.
2. The mammary gland.

THE OVARIES

These are oval structures, 1 inch (2.5 centimetres) in length and ½ inch (1 centimetre) in width, lying on the lateral walls of the pelvic cavity on either side of the uterus and suspended from a peritoneal sheet, the *broad ligament of the uterus*, which stretches laterally from the uterus to reach the pelvic wall on either side and below. In the free upper border of the broad ligament run the uterine tubes (see below) and the ovaries are suspended from its posterior surface. The ovarian and uterine blood vessels and lymphatics run between the layers of the ligament.

Structure of the ovary. Each ovary consists of fibrous tissue in which lie several thousand islands of cells derived during foetal life from the germinal epithelium, which lies immediately beneath the fibrous tissue capsule. These islands of cells are known as *Graafian follicles* and each contains an *ovum* or egg cell and secretes a hormone, *oestrogen* (see p. 239). Every month a Graafian follicle migrates to the periphery of the ovary and ruptures, ejecting the *ovum* which it contains into the peritoneal cavity in the neighbourhood of the internal opening of one of the uterine tubes. After discharging the ovum the follicle

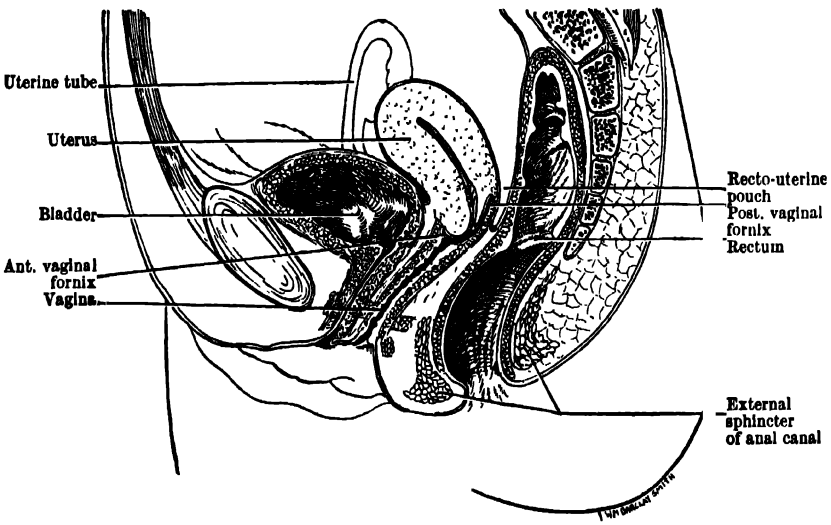


Fig. 15.4 Sagittal section of the female pelvis.

increases in size and becomes yellow, forming the *corpus luteum.* Unless pregnancy occurs this corpus luteum degenerates but if pregnancy should take place the corpus luteum increases in size and produces a hormone (p. 239) called *progesterone* which is essential for the retention of the foetus in the uterus.

THE UTERUS

The uterus or womb when seen from the front is a pear-shaped organ measuring 3 inches (7.5 centimetres) long and 2 inches (5 centimetres) wide. It is flattened from front to back measuring about 1 inch (2.5 centimetres) in thickness and it is divided into three parts, the fundus, the body and the cervix. It is situated between the

bladder and the rectum and is covered anteriorly and posteriorly by peritoneum which forms a double fold on either side known as the *broad ligament* of the uterus. On either side of the *fundus* are the upper corners or *fornices* (sing. *fornix*) from which the uterine tubes run laterally in the upper parts of the broad ligaments. The *two round ligaments* also run in the broad ligaments and help to support the organ.

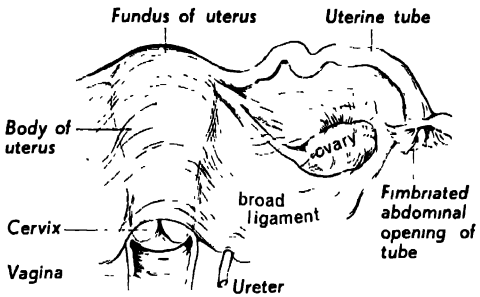


Fig. 15.5 Diagram of a specimen showing the uterus, the uterine tube, the ovary and adjacent structures of the right side, seen from behind.

The lowest portion of the uterus is the *cervix* or neck and its lower end, the *external os*, projects into the vault of the vagina. The cavity of the cervix is called the *cervical canal* and the *internal os* marks the junction of the uterine cavity with that of the cervix.

The uterus is composed principally of muscle, the *myometrium*, and its interior is lined by a mucous membrane known as the *endometrium*. This is smooth in appearance in the body of the uterus but ridged in the cervix.

The uterus derives its blood supply from the uterine artery on each side which arises from the internal iliac (hypogastric) artery. These arteries cross the pelvic floor and run upwards in the broad ligament; near the cervix they are in front of the ureter and because of this relationship the ureter can be damaged during operations on this part of the uterus.

The lymphatic drainage of the uterus and cervix is considered elsewhere (p. 165).

The *function* of the uterus is, of course, to provide suitable surroundings for the development of the foetus and this necessitates a complex series of changes in the endometrium to maintain its state of

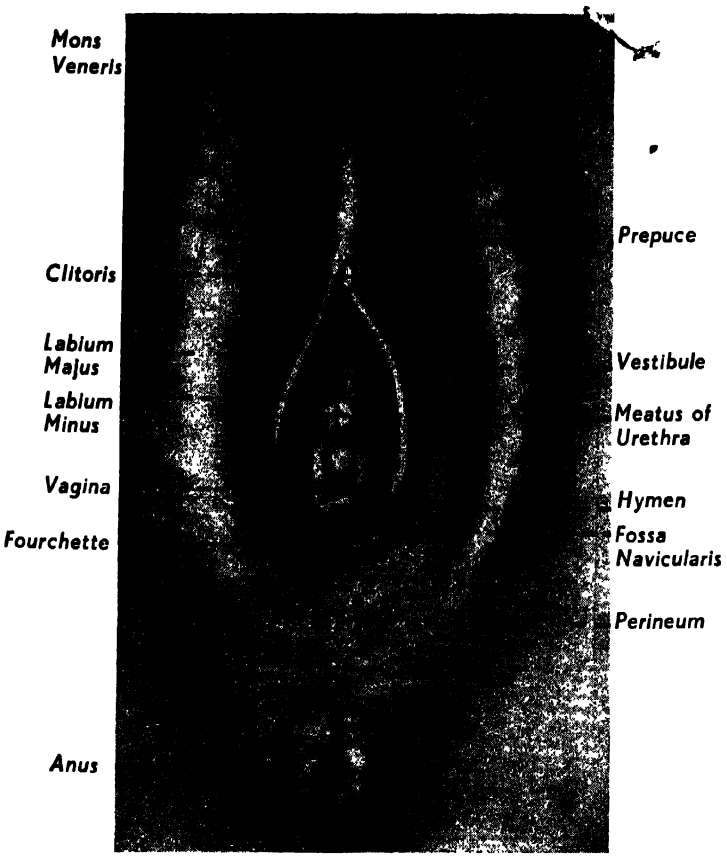


Fig. 15.6 The external genital organs of the female.

preparation for such an event (see Menstruation and Ovulation page 226).

THE UTERINE TUBES (the Fallopian tubes)

These are hollow muscular tubes lined by ciliated columnar epithelium, they are about 4½ inches (11 centimetres) in length and they conduct the ovum into the uterus. Fertilization of the ovum by the spermatozoon usually occurs in them. The tubes run in the upper margin of the broad ligaments and are divisible into an *intramural* portion in the walls of the uterus, a narrow *isthmus* and a wider *ampulla* which leads to the *infundibulum* from which a number of

processes or *fimbriae* project. The ovary lies close to the infundibulum and the fimbriae presumably help to direct the ovum into the tube.

THE VAGINA

The vagina runs from the external os of the cervix to the vulva. It is lined by skin moistened by the mucous glands of the cervix, which projects into the upper part or vault. There is a recess or *fornix* surrounding the cervix which is largest posteriorly where it is called the posterior fornix and above this is the lowest part of the peritoneal cavity, the recto-uterine pouch (of Douglas) (p. 185). The bladder and urethra are anterior to the vagina and the rectum is posterior to the upper part of it. The lower part of the vagina is separated from the anal canal by the *perineal body* – a mass of fibrous and muscular tissue which is capable of stretching greatly during labour. The lower end of the vagina is partially closed by the *hymen* in the virgin state.

The lymphatic drainage has been dealt with elsewhere (p. 165).

THE VULVA

The vulva is a cleft through which the urethra and the vagina open. It is bounded on either side by the *labia majora* which run from the *mons veneris* anteriorly to the *perineum*, the region between the vulva and the anus, posteriorly. The mons veneris lies over the symphysis pubis and bears hairs after puberty. At the posterior end of each labium majus is a mucous gland, Bartholin's gland.

The *labia minora* lie medial to the labia majora and meet anteriorly forming the prepuce of the *clitoris*, a small erectile structure related embryologically to the penis. The labia minora meet posteriorly in a fold called the *fourchette*. The opening of the urethra is anterior to the vaginal orifice.

THE BREASTS

These are accessory organs of reproduction and develop fully in the female after puberty. They are circular in outline and contain much fat so that they vary greatly in size from individual to individual. They lie between the lateral border of the sternum and the axilla on the pectoralis major muscle from the level of the second rib above to the sixth rib below.

The breast consists of a series of lobules from each of which a *lactiferous duct* runs; after dilating to form the *ampulla* each duct

converges on the nipple and opens on its surface. The *nipple* is a small raised area surrounded by the pigmented *areola*.

The lymphatic drainage has been dealt with elsewhere (p. 164).

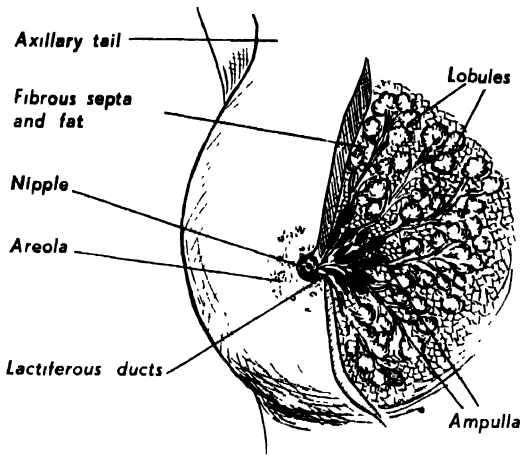


Fig. 15.7 Diagram to show the structure of right breast.

MENSTRUATION AND OVULATION

The endometrium undergoes a complicated cycle of changes every month in preparation for the possible arrival of a fertilized ovum. These changes start at *puberty* and continue until the *climacteric* or *menopause* which occurs between 45 and 50 years of age; after it the woman is unable to reproduce. The cycle is controlled by hormones (Chapter 16) secreted by the ovaries and the pituitary gland and as the cycle lasts approximately 1 month it is called *menstruation.*

There are four stages in the menstrual cycle. The *resting stage* lasts about 10 days; it occupies the middle of the cycle and *ovulation* (the shedding of the ovum by the ovary) occurs during it. This is followed by the *premenstrual* (constructive) stage which lasts about 6 days and is accompanied by hypertrophy and engorgement of the endometrium. Then some of the epithelium is shed and bleeding occurs during the 5 days or so of the *destructive stage* which causes the menstrual flow. The last stage, that of *repair* follows and occupies about 7 days.

The object of menstruation is achieved if pregnancy occurs and the developing corpus luteum of pregnancy suppresses the menstrual cycle. Menstruation does not usually recommence until lactation has ceased.

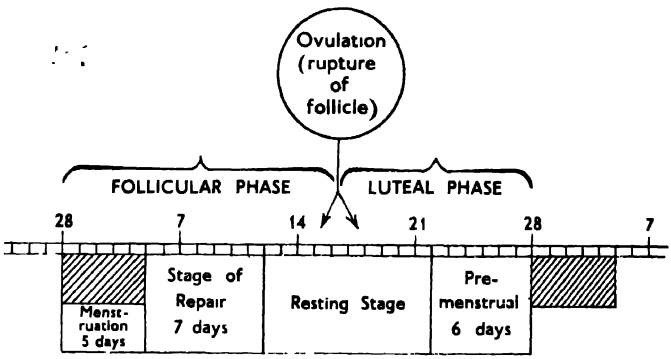


Fig. 15.8 Diagram to illustrate the menstrual cycle.

PREGNANCY

The consequences of fertilization of the ovum have already been briefly described (p. 7). Certain maternal changes occur during pregnancy and amongst these are increase in the size of the breasts and pigmentation of the areolae. The uterus enlarges and estimation of the height of the fundus by abdominal palpation is an approximate method of assessing the age of the foetus. During the latter part of pregnancy the pelvic ligaments undergo softening so as to allow the sacro-iliac joints and symphysis pubis to stretch during labour. Approximately 280 days after conception uterine contractions commence, the cervix and vagina progressively dilate, the perineum stretches, the amniotic fluid surrounding the foetus drains away and the birth of the child follows. There is usually a short delay before the placenta is expelled so the umbilical cord which attaches the infant to the placenta is divided between ligatures.

Lactation

As term approaches a clear fluid called *colostrum* is secreted by the breast and this is followed a few days after delivery by the secretion of milk. The pituitary gland stimulates the breast into activity but the continued secretion of milk also requires regular emptying of the lactiferous ducts.

The Radiographic Appearances of the Female Genital Tract

The female genital tract may be demonstrated by radiography after the instillation through the external os of iodized poppy-seed

oil or viscous iodine preparations (hysterosalpingography). The cervical canal, the uterine cavity and the various parts of the uterine tubes will be demonstrated and patency of one or both uterine tubes will be shown by the entry into the peritoneal cavity of some of the opaque medium.

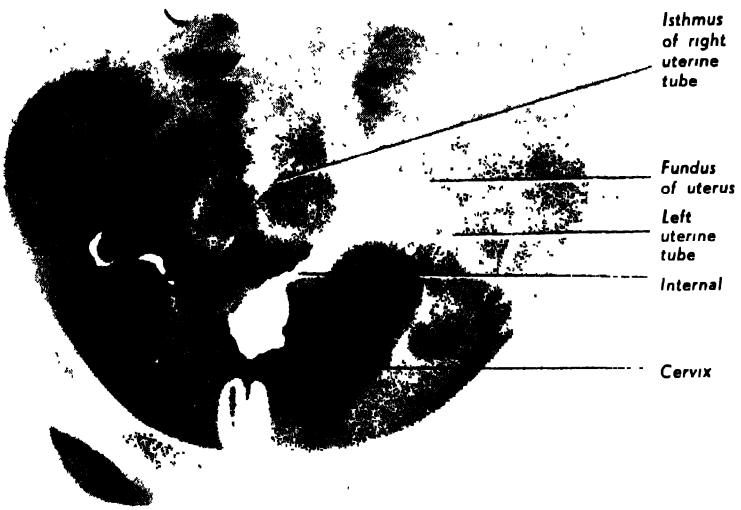


Fig. 15.9 Radiograph of the female genital tract after the injection of an opaque medium. (The uterus normally is not flexed to the left as in this subject.)

Pathological Considerations of the Male Genital Tract

Radiographic investigation of the male urethra (*urethrography*) may be required in the investigation of congenital urethral *valves* (usually in infancy) and *strictures* which may be traumatic (e.g. following fractures of the pelvis) or due to infection (e.g. gonorrhoea).

The prostate is liable to become enlarged in the elderly by a non-malignant condition which may constrict the urethra. The kidneys may be damaged by the resulting obstruction to the emptying of the bladder and excretion urography may be required in the planning of surgical treatment.

The prostate may also be the site of carcinoma and this tumour, and the secondary deposits which tend to attack the skeleton, are often dramatically improved by treatment with female sex hormone.

The testis may be the site of malignant tumour formation (*seminoma* in young adults, *teratoma* in older patients) and because of its

lymphatic drainage nodes of the aortic group may become involved and require treatment.

Pathological Considerations of the Female Genital Tract

Gynaecological disorders are often associated with disorders of menstruation and a number of terms are used to describe these.

Painful menstruation is called *dysmenorrhoea*. Failure to menstruate is called *amenorrhoea* and it is, of course, a normal state during pregnancy. Excessive blood loss during menstruation is called *menorrhagia*.

Inflammation of the uterine tubes is called *salpingitis* and pregnancy occurring in a uterine tube instead of in the uterus is called a *tubal* (or *ectopic*) *pregnancy*.

Radiographic study by hysterosalpingography may be required in cases of sterility and infertility to determine whether the tubes are blocked or patent.

Radiography of the pregnant uterus may be called for in the diagnosis of twins, foetal abnormalities, foetal maturity, placental localization, etc., and the diameters of the pelvis may be measured by radiological pelvimetry.

Radiography has an important part to play in placental localization because a placenta implanted in the lower part of the uterus may obstruct labour and cause dangerous bleeding. The placenta may be localized by plain radiography or by arteriography.

The uterus may develop tumours of the myometrium. These are usually non-malignant and are known as *fibroids*. *Cancer of the uterus* may occur and it arises in the endometrium either of the body or the cervix of the organ. *Cancer of the cervix* is particularly prone to involve the ureters when it spreads locally, so excretion urography may be called for in the planning of treatment.

The ovary is liable to develop cysts which sometimes attain great size and tumours which may be innocent or malignant.

The breast is liable to a number of diseases. These include *chronic mastitis*, a non-malignant proliferation of tissue with cyst formation, and *carcinoma* which is, of course, all too common in women of the fourth and fifth decades. It may be treated by radiotherapy alone or by a combination of radiotherapy and surgery.

16

The Endocrine System

The endocrine system is made up of a number of glands whose secretions or *hormones* pass directly into the blood stream. The *ductless glands* are not in fact the only sources of hormones as certain parts of the alimentary tract also produce hormones.

The hormones are often called chemical messengers and because they are carried round in the blood stream they are likely to produce very widespread effects. Their action may be studied by observing the results of pathological oversecretion and undersecretion of the glands which produce them, and by observing the effects of giving the dried extract of the gland or the synthetic hormone to human beings.

Some glands function both as glands of external secretion and as ductless glands. These functions are usually quite distinct and unrelated; for example, the external secretion of the pancreas is the pancreatic juice and its internal secretion is insulin.

THE PITUITARY GLAND

The pituitary gland is of great importance in the body for, in addition to producing hormones which have a direct effect on tissues, it produces a number of hormones which exert a controlling influence on other endocrine glands. The pituitary gland has been, in fact, very aptly termed 'the conductor of the endocrine orchestra'. It is a single midline structure about 1 centimetre in diameter lying in the sella turcica (p. 41) and connected to the brain by a stalk through which nerve tracts run to that part of the brain known as the hypothalamus. The gland is closely related in position to the optic nerves which join to form the optic chiasma just above and anterior to it. This relationship is important in that tumours of the pituitary gland may exert pressure on the optic nerves and the chiasma leading to visual disturbances including blindness.

The pituitary gland is composed of an anterior and a posterior lobe, both of which are hormone-secreting, and these are separated by a middle part which does not appear to secrete any hormones.

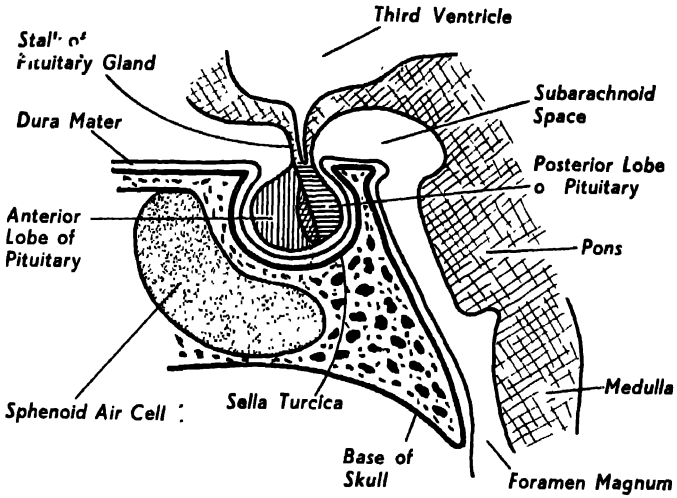


Fig. 16.1 Diagram illustrating the pituitary gland.

The *function of the anterior lobe* of the pituitary gland is to produce the following hormones:

1. *Growth hormone.* This hormone influences the growth of tissues, particularly the skeleton. Production of this hormone appears to be well regulated as pathological states resulting from overproduction and underproduction of this hormone are rare.

2. *Thyroid-stimulating hormone* (*T.S.H.*). The thyroid-stimulating hormone controls the activity of the thyroid gland. A rise in the amount of T.S.H. secreted by the pituitary results in a rise in the amount of thyroxin secreted by the thyroid gland.

3. *Adrenocorticotrophic hormone* (*A.C.T.H.*). A.C.T.H. stimulates the cortex of the adrenal glands to secrete hydrocortisone. Alterations in the amount of A.C.T.H. secreted by the pituitary result in alterations in hydrocortisone output by the suprarenal glands.

4. *Prolactin.* Prolactin is only thought to be of significance in the lactating woman in whom it is partly responsible for the production of milk by the breast.

5. *Follicle-stimulating hormone.* (*F.S.H.*). F.S.H. in the female stimulates the development of the Graafian follicle and stimulates the mature follicle to produce oestrogen. In the male F.S.H. stimulates the production of spermatozoa.

6. *Luteinizing hormone.* The luteinizing hormone in the female stimulates the formation of the corpus luteum after ovulation and the secretion of progesterone by the corpus luteum. In the male the

luteinizing hormone stimulates the interstitial cells of the testis to produce testosterone. Thus the luteinizing hormone is mainly concerned with the production of the sex hormones whilst the follicle-stimulating hormone is mainly concerned with the production of the germ cells, the ova and the spermatozoa.

The *function of the posterior lobe* of the pituitary gland is to produce the following hormones:

1. The *antidiuretic hormone* (*A.D.H.*). A *diuresis* is the passage of a quantity of dilute urine after drinking a large volume of fluid and as the name suggests A.D.H. opposes the diuresis under these circumstances. A.D.H. plays a vital role in the control of the total amount of water in the body. After consuming large quantities of fluid it is usual to experience a diuresis and this occurs because under these circumstances the secretion of A.D.H. by the pituitary *falls* allowing diuresis to occur. A.D.H. controls the output of urine by controlling the amount absorbed by the distal tubules of the kidney. Under conditions of water deprivation A.D.H. is secreted in large amounts and the distal tubules absorb most of the water passing through the kidney. Only a small amount of highly concentrated urine is passed and thus water is conserved for use by the body. A.D.H. is also secreted in larger amounts at night and thus the amount of urine formed during sleep is much less than during the daytime.

2. *Pituitrin.* This is the other hormone secreted by the posterior lobe of the pituitary gland, it is apparently less important physiologically than the antidiuretic hormone. It causes smooth muscle such as that of the walls of blood vessels, bowel, bladder and uterus to contract.

Pathological Considerations

The importance of the relationship of the pituitary gland to the optic chiasma has already been referred to.

In childhood overproduction of growth hormone results in a young individual becoming excessively tall (*gigantism*) whilst underproduction results in dwarfism. Overproduction of growth hormone in the adult produces the condition known as *acromegaly*. Acromegaly is characterized by coarsening of the patient's appearance and enlargement and thickening of bones, particularly the mandible, and the bones of the hands. In the advanced stage the patient is pathetically grotesque in appearance. One of the effects of lack of function by the posterior lobe is the passage of very large quantities of dilute urine, the condition known as *diabetes insipidus*.

THE THYROID GLAND

The thyroid gland is situated in the neck in close relationship with the larynx and the upper part of the trachea at the level of the lower three cervical and first thoracic vertebrae. It consists of two lobes which are joined by an isthmus. The lobes are conical in shape and lie on either side of the lower part of the larynx and the cervical portion of the trachea anterior to the recurrent laryngeal nerves (which supply the larynx), the parathyroid glands, the common

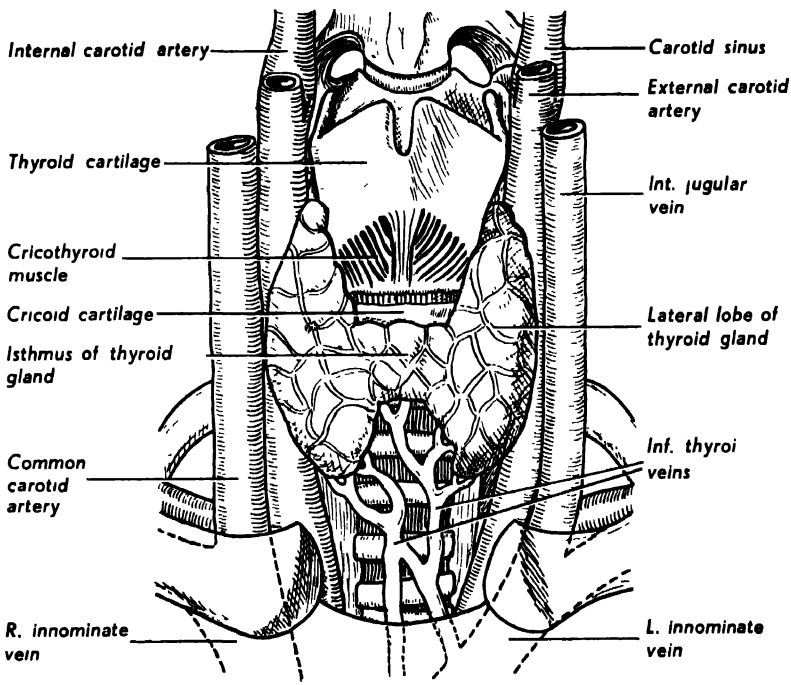


Fig. 16.2 The thyroid gland.

carotid arteries and the internal jugular veins. The isthmus lies on the anterior surface of the trachea and intervening between the gland and the skin are the thin pretracheal muscles and the sterno-mastoid muscles.

The functions of the thyroid gland are concerned with iodine which it extracts, from the blood, concentrates and stores. It produces the hormone *thyroxin* which it also stores so that it is ready for secretion into the blood stream. As has already been indicated

the thyroid is stimulated to secrete thyroxin into the blood stream by the thyroid stimulating hormone secreted by the pituitary gland. The thyroid hormone, thyroxin, exerts a controlling influence on the metabolic rate of tissues and normal thyroid function is required for normal mental, sexual and skeletal development.

Pathological Considerations

Diseases of the thyroid gland are commonly encountered in hospital practice. Enlargements of the thyroid gland are termed *goitres*; goitres are usually located in the neck but sometimes are partially or wholly behind the sternum. The presence of a goitre in the retrosternal position may be demonstrated radiographically. A goitre may not be associated with any overactivity of the gland when it is termed a *non-toxic goitre*. On the other hand the goitre may be accompanied by oversecretion of thyroxin when it is termed a *toxic goitre*.

Oversecretion of thyroxin produces a condition termed *thyrotoxicosis* (hyperthyroidism). The excessive amount of circulating thyroxin produces acceleration of the metabolic rate and this leads to emotional disturbances, rapid heart rate, poor toleration of heat, loss of weight and sometimes protrusion of the eyes (exophthalmos).

On the other hand undersecretion of thyroxin produces an entirely different picture: in infancy it causes *cretinism* a form of mental defect associated with dwarfism and retardation of both skeletal and sexual development. In adults undersecretion results in myxoedema (hypothyroidism), a condition characterized by mental apathy and dullness, a coarsened appearance, intolerance of cold, thinning and loss of lustre of the hair and other manifestations of the slowing down of metabolism.

Iodine has been mentioned as an important component of the thyroxin molecule. The body requires only minute quantities of iodine amounts which are readily obtained from the normal foodstuffs in most areas. In certain mountainous areas the soil is poor in iodine and consequently the diet of the inhabitants of these regions may be deficient in iodine. The result is that the development of a goitre during puberty is not uncommon in that region, e.g. 'Derbyshire neck'. Only rarely, however, is the deficiency in iodine sufficient to result in undersecretion of thyroxin. The condition can be prevented by the simple expedient of adding small quantities of iodine to table salt, a method which has had marked success in Switzerland.

The Parathyroid Glands

These are small pea-like structures, usually four in number, which are embedded, two on each side, in the posterior aspect of the lobes of the thyroid gland. The close anatomical association of the parathyroid glands with the thyroid gland gives them their name but functionally they are quite distinct.

The *function of the parathyroid glands* is to secrete a hormone *parathormone* which plays a vital role in the regulation of the amounts of calcium and phosphorus in the blood and bone.

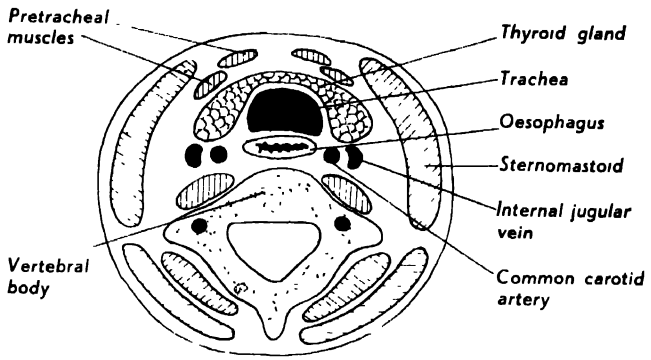


Fig. 16.3 Transverse section of the lower part of the neck showing the thyroid gland, etc.

Pathological Considerations

Conditions resulting from disordered activity of these glands are rare. Overactivity or *hyperparathyroidism* is associated with withdrawal of calcium from the bones, elevation of the level of calcium in the blood and the deposition of calcium in sites such as the kidneys and blood vessels. The withdrawal of calcium from the bones may lead to the development of bone deformities and the occurrence of fractures as a result of relatively minor trauma. Underactivity of the glands or hypoparathyroidism results in a lowering of the level of the blood calcium. The main effect of the lowering of the blood calcium is the occurrence of a form of muscle spasm known as *tetany*.

THE THYMUS GLAND

This gland is situated in the anterior mediastinum between the heart and great vessels behind and the sternum in front. Knowledge

about its function is meagre. It is relatively large in infancy but it atrophies after puberty.

Pathological Considerations

In babies the thymus may be seen in radiographs of the chest. In the rare disease myasthenia gravis a thymic tumour may be present; it may then be demonstrable radiographically and its removal may be very beneficial.

THE SUPRARENAL GLANDS

The suprarenal or adrenal glands are situated at the upper pole of each kidney; they are related posteriorly to the diaphragm and anteriorly they form part of the stomach bed lying in the posterior wall of the lesser sac of the peritoneum. The right is related anteriorly to the inferior vena cava and the liver. Each gland consists of an outer part, the cortex, which surrounds the inner part, the medulla. The two parts of the suprarenal gland can be regarded separately because they have a different structure microscopically and they secrete groups of hormones with distinctly different functions. The cortex of the suprarenal is essential to life whilst the medulla is not.

The *function of the suprarenal cortex* is to produce the following hormones:

1. *Hydrocortisone* and *aldosterone* which affect the metabolism of water, minerals, carbohydrate, protein and fat. Hydrocortisone is an extremely important hormone and has a very wide use in medicine. This is because the 'steroid' hormones, hydrocortisone and its analogues, have very marked damping effect on inflammatory reactions quite apart from their effects on metabolism. Thus the benefit obtained in, for example, a dermatitis or an arthritis is largely due to this damping effect on inflammation. The excretion of hydrocortisone is regulated by A.C.T.H. from the pituitary. The action of aldosterone is complex and can be ignored.

2. *Sex hormones*, the cortex of the suprarenal gland produces small quantities of hormones similar to oestrogen in the female (see p. 239) and testosterone in the male (see p. 239). These hormones are produced *both* in males and females and thus there are always small quantities of female sex hormones in the male and vice versa.

The suprarenal medulla

The *function of the suprarenal medulla* is to secrete two hormones

noradrenaline and *adrenaline* which have roughly similar actions. These actions mobilize the body for sudden activity in response to stress, an effect which has been termed the 'fight or flight reaction'. The effects produced are similar to stimulation of the sympathetic nervous system, an effect which is more understandable when it is realized that the adrenal medulla is, in fact, a part of the sympathetic nervous system. The administration of adrenaline constricts the blood vessels of the skin and the intestines, diverting blood to the muscles, heart and brain, it raises the blood pressure and increases the heart rate, dilates the pupils and the bronchi and produces a number of other effects. These effects can be readily observed in individuals who are alarmed and they prepare the individual to respond more fully to the initial stimulus.

Pathological Considerations

Bilateral destruction of the cortical parts of the glands by tuberculosis resulting in undersecretion of cortical hormones, known as *Addison's disease*, is encountered less commonly at the present time than formerly. Addison's disease, if untreated, may result in death from loss of sodium chloride in the urine and general loss of resistance to stress and infection. The patient with classical Addison's disease is wasted and shows a characteristic pigmentation of the skin and the mucous membranes.

The condition of overactivity of the adrenal glands results in *Cushing's syndrome*. Patients with Cushing's syndrome have a characteristic obesity with particular involvement of the trunk and the face ('moon face'), overgrowth of hair, particularly facial hair, hypertension and many other features.

Very rarely indeed the sex hormones are excreted in excess resulting usually in *virilism* i.e. the exaggeration of the male characteristics so that women develop certain masculine features and boys reach puberty at an unusually early age.

The value of cortisone in medicine has already been referred to (see p. 236).

THE PANCREAS

The gross anatomy of the pancreas has already been described (p. 204). It will be recalled that this is one of the glands which produce both an external and an internal secretion. The former is, of course, a digestive juice which is discharged through the pancreatic duct.

The *endocrine function of the pancreas* is to secrete insulin; this hormone is produced by small groups of specialized cells which are scattered amongst those which are concerned with the production of the external secretion. These small groups of cells are termed the islets of Langerhans and can be readily identified on microscopic examination of pancreatic tissue.

Insulin regulates carbohydrate metabolism and is secreted in response to a rise in the blood sugar level such as occurs during the digestion and absorption of food. Insulin causes the liver to store carbohydrate as glycogen (a derivative of glucose), enables the tissues to utilize carbohydrate and promotes the conversion of carbohydrates to fat for storage. Insulin therefore has a tendency to lower the blood sugar but the amount of insulin secreted is normally well regulated and insulin secretion is curtailed if the blood sugar falls below the average level. On the other hand insulin, given therapeutically for diabetes mellitus can, if care is not taken with the dosage and the diet, lower the blood sugar sufficiently to cause symptoms. The patient is said to be suffering then from *hypoglycaemia* and the effects are often very bizarre. Mental symptoms are prominent and may take the form of restlessness or anxiety, excitement, apathy or 'drunkenness'. The patient may complain of hunger and may show sweating, tremor and a raised pulse rate. If the hypoglycaemia is severe unconsciousness and even death may result. The radiographer must be aware of this condition as from time to time one encounters it in patients undergoing radiographic examination. The treatment is the administration of carbohydrate as quickly and as safely as possible. If the patient can swallow, glucose or cane sugar in water must be given but if the patient is unconscious glucose must be given intravenously. Recovery with correct treatment is prompt.

Pathological Considerations

Absolute or relative lack of insulin results in *diabetes mellitus*. The patients are unable to metabolize glucose with the result that the blood glucose level rises and glucose is excreted in the urine, where it can easily be detected by simple chemical tests. The carbohydrates absorbed from the gut cannot be properly utilized and the patient loses weight and strength. Energy stores such as fat are burned up to provide energy for the body to function but this leads to the accumulation of organic acids, the by-products of the metabolism of fat, in the blood. This accumulation of organic acids may be so severe as to to cause coma. The passage of large quantities of glucose in the urine causes a diuresis; the patients are often troubled by the

excessive amounts of urine they pass and the consequent troublesome thirst. Resistance to infections is lowered and the incidence of pulmonary tuberculosis is appreciably higher in diabetics. Patients with diabetes have a tendency to develop arterial disease and this may lead to gangrene especially of the feet.

THE GONADS

The gonads or sex glands, like the pancreas, may be regarded as being glands which produce both external and internal secretions. We are only concerned with the latter in this section.

The interstitial tissue of the testis, under the stimulus of the luteinizing hormone of the anterior lobe of the pituitary gland, produces *testosterone*. This is the hormone responsible for the secondary sexual characteristics which develop at puberty and include the distribution of hair on the face and body, the distribution of subcutaneous fat, and the changes in the voice, the shape of the pelvis and mental attributes which characterize the male sex.

Oestrogen, the secretion of the Graafian follicle resulting from stimulation of the ovary by the follicle-stimulating hormone of the anterior lobe of the pituitary gland is responsible for the secondary sexual characteristics and the breast development which occurs in the female at puberty. Oestrogen is also responsible for the endometrial changes which characterize the destructive and reparative stages of the menstrual cycle.

After ovulation (p. 226) the corpus luteum is responsible for the hypertrophy and engorgement of the endometrium which occurs during the constructive (premenstrual) phase of the menstrual cycle. During pregnancy, however, the corpus luteum is stimulated by the luteinizing hormone of the pituitary gland to continue the secretion of *progesterone* since this hormone is essential for the retention of the foetus in the uterus. The corpus luteum therefore persists throughout pregnancy.

Pathological Considerations

Removal of the gonads in a young individual before puberty will result in the non-appearance of secondary sexual characteristics. In adult life such a procedure has much less effect. It has been found that some cases of advanced malignant disease benefit from removal of the gonads, thus in women with advanced carcinoma of the breast the operation of removal of the ovaries may be followed by regression of secondary deposits.

THE PINEAL BODY

This structure is usually considered with the ductless glands but it has no known function. It is situated in the midline within the skull between the under surface of the cerebrum and the mid-brain. It is frequently calcified and visible in radiographs (Fig. 6.17a).

17

The Nervous System

The nervous system is a complex mechanism which regulates many bodily activities. It consists of supporting tissue called *neuroglia* and large numbers of *nerve-cells*, most of which bear at least two processes called *nerve-fibres*.

A nerve-cell with its fibres is called a *neuron* and an *afferent neuron* carries information from nerve endings, such as those in the skin, muscles and joints, to the brain and spinal cord. An *efferent neuron* conducts from the brain and spinal cord impulses such as those which cause muscles to contract and relax and glands to secrete. The nerve-cells of the brain are situated in a superficial layer called the *grey matter* and the nerve-fibres make up the *white matter* which lies deep to this. In the spinal cord the grey matter lies deeply and the white matter is superficial.

The nervous system is made up of:

(1) The central nervous system consisting of the brain and spinal cord.

(2) The peripheral nervous system which connects the various parts of the body with the central nervous system.

(3) The autonomic nervous system which is concerned with the involuntary or vegetative functions of the body.

THE BRAIN

The human brain is a large and complex structure which will be better understood if some stages in its development are briefly described.

The nervous system develops from the ectoderm as a thickened plate on the surface of the embryo, it then sinks below the surface and becomes converted into a tube. Part of this tube becomes the spinal cord, but the head-end enlarges to form the future brain and three parts containing cavities or ventricles can be recognized: the

fore-brain, the mid-brain and the hind-brain. The fore-brain expands laterally on each side to form the cerebral hemispheres which increase greatly in size and eventually envelop most of the rest of the brain.

The chief parts of the brain may be tabulated according to their developmental origin.

(1) The fore-brain gives rise to:
 (*a*) The cerebral hemispheres or cerebrum.
 (*b*) The thalamus and hypothalamus.
(2) The mid-brain gives rise to:
 The cerebral peduncles.

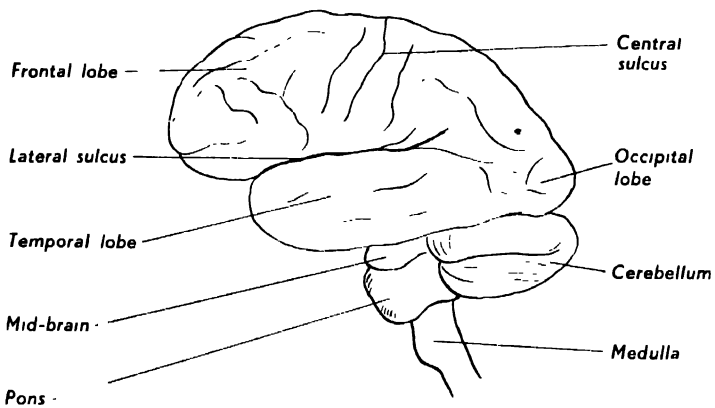


Fig. 17.1 Diagram illustrating the left lateral aspect of the brain.

(3) The hind-brain gives rise to:
 (*a*) The pons.
 (*b*) The medulla oblongata
 (*c*) The cerebellum.

The Cerebrum

This consists of the right and left cerebral hemispheres, it is the most conspicuous feature of the human brain and occupies the anterior and middle cranial fossae. The surface layer or cortex consists of grey matter which is folded into *convolutions* or *gyri* separated by *sulci*, an arrangement which greatly increases the amount of grey matter relative to the size of the brain. The interior is composed of white matter and contains the lateral ventricles.

Each hemisphere is divided for descriptive purposes into frontal,

parietal, occipital and temporal lobes which take their names from the overlying bones. A sulcus called the *central sulcus* separates the frontal from the parietal lobes and runs downwards almost to the *lateral sulcus* which separates the temporal from the frontal and parietal lobes. In front of the central sulcus is the *motor cortex* or precentral gyrus where all voluntary movements are initiated and behind the sulcus is the *sensory cortex* or postcentral gyrus where most sensory impressions are received. The occipital lobe is concerned with sight; other areas of the cortex can be mapped out where various functions are controlled such as hearing, writing, speech, etc.

The **functions of the cerebrum** are the initiation of all voluntary movement, the reception of all sensory impressions and the correlation of these activities resulting in speech, language, thought, intelligence, memory, etc.

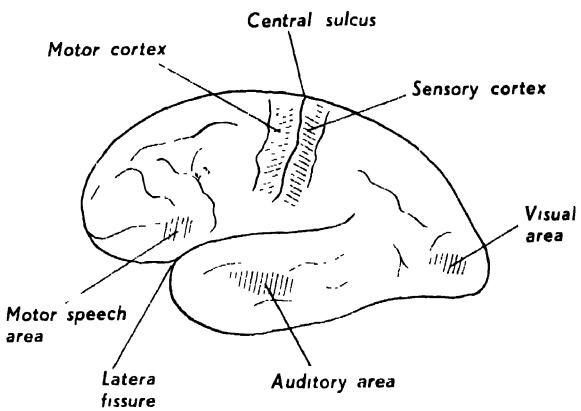


Fig. 17.2 Diagram illustrating the localization of some functions in the left cerebral hemisphere.

The **mid-brain** consists of the cerebral peduncles and it connects the cerebral hemispheres to the pons. Its cavity is a narrow canal, the aqueduct.

The **pons** connects the cerebral peduncles to the medulla oblongata and it also connects the two cerebellar hemispheres to each other.

The **medulla oblongata** lies just in front of the foramen magnum and intervenes between the pons and the spinal cord. There are centres in it which control breathing, the action of the heart, the calibre of the blood vessels and such reflex activities as swallowing

and vomiting, the movements of the alimentary canal and the secretion of the digestive juices

The **cerebellum** lies in the posterior cranial fossa; its surface is thrown into folds and it is divided into right and left lobes which are connected by the pons. Its functions, which are not under voluntary control, are to co-ordinate muscular movement and to maintain balance and equilibrium.

THE VENTRICULAR SYSTEM OF THE BRAIN

The cerebral hemispheres each contain a *lateral ventricle* and these are the largest cavities within the brain. Each communicates by the interventricular foramen with the third ventricle and each has an anterior horn, a body, a posterior and a temporal horn. The last

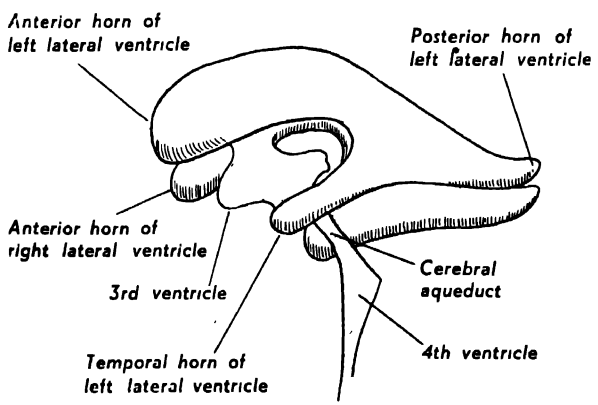


Fig. 17.3 Diagram illustrating the ventricles of the brain.

of these runs into the temporal lobe. The *third ventricle* is the cavity of the fore-brain and lies between the two thalami; in addition to communicating with each lateral ventricle it is joined posteriorly by the aqueduct.

The cavities of the mid-brain and hind-brain are the *aqueduct* and the *fourth ventricle* respectively. The *central canal* of the spinal cord runs downwards from the fourth ventricle and in the roof of this ventricle are apertures through which the cerebrospinal fluid passes into the *subarachnoid space* which intervenes between the arachnoid mater and pia mater, two of the meninges or membranes covering the brain (p. 251). Capillary tufts called *choroid plexuses* project into the ventricles from their roofs and produce the cerebrospinal fluid (p. 252).

THE CRANIAL NERVES

There are twelve pairs of nerves arising from the brain; some are afferent (sensory), some are efferent (motor) and some are mixed.

(I) The *olfactory* is sensory and is the nerve of smell.

(II) The *optic* is sensory and is the nerve of sight. It begins in the

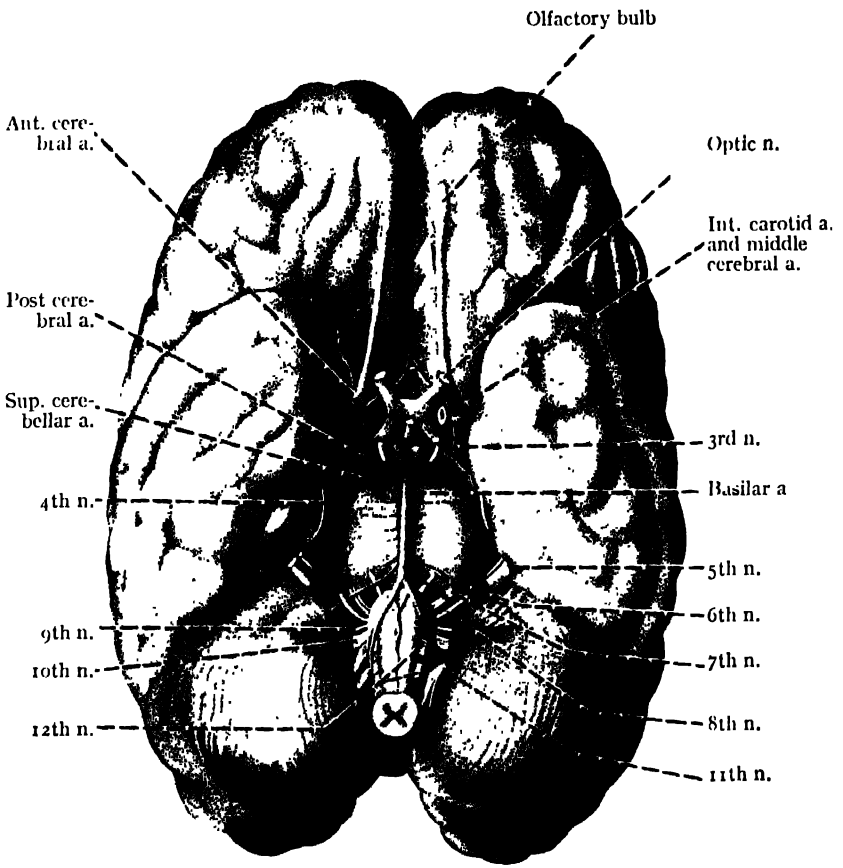


Fig. 17.4 The base of the brain.

retina of the eye and passes through the orbit and optic canal to reach the interior of the skull where many fibres from each eye cross to the opposite side at the *optic chiasma* and then continue on into the brain to the occipital part of the cerebral cortex (Fig. 18.2).

(III) The *occulomotor*, (IV) the *trochlear* and (VI) the *abducent* are all motor to the muscles of the eyeball.

(V) The *trigeminal* is sensory to the face and forehead and motor to the muscles of mastication.

(VII) The *facial* is motor to the muscles of facial expression. It runs with the auditory in the internal auditory meatus and then passes close to the mastoid air cells and the middle ear.

(VIII) The *auditory* is sensory and is concerned with hearing and balance.

(IX) The *glossopharyngeal* is a mixed nerve supplying the pharynx and the tongue.

(X) The *vagus* is mixed and supplies most of the alimentary canal, the respiratory tract and the heart.

(XI) and (XII) These are both motor. The former is the *spinal accessory* and supplies the trapezius and sternomastoid muscles, and the latter, the *hypoglossal*, supplies the muscles of the tongue.

THE SPINAL CORD

The spinal cord lies in the spinal canal and extends for about 18 inches below the foramen magnum, ending at the level of the first lumbar vertebra in the adult. It shows two enlargements, one in the cervical region and the other between the ninth and twelfth thoracic vertebrae, called the lumbar enlargement. From its lower end opposite the first lumbar vertebra a fibrous strand, the *filum terminale*, runs down to the second sacral vertebra. As the cord is so much shorter than the spinal canal the lumbar, sacral and coccygeal nerves run from the lumbar enlargement to the lumbar intervertebral and sacral foramina, forming a leash of nerves accompanying the filum terminale known as the *cauda equina*.

The spinal cord is composed of grey matter which, unlike that of the brain, is placed deeply as an H-shaped column surrounding the central canal. The four processes of the H are the two *anterior* and two *posterior horns* and in front, behind and on either side of the grey matter is the white matter which, like that of the brain, consists of nerve-fibres.

The **functions of the spinal cord** are:

(1) To transmit afferent (sensory) impressions to the brain and efferent (motor) impulses from the brain.

(2) To take part in a type of activity known as *reflex action*.

THE SPINAL NERVES

There are 31 pairs of spinal nerves comprising 8 cervical, 12 thoracic, 5 lumbar, 5 sacral and 1 coccygeal. Each leaves the cord

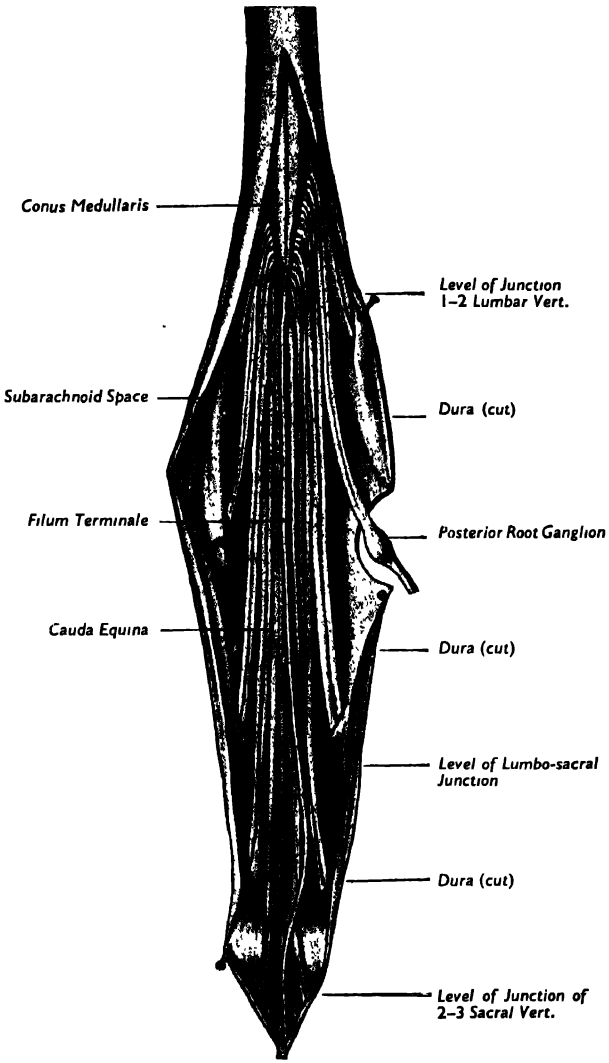


Fig. 17.5 The lower end of the dura and arachnoid laid open to expose the cauda equina.

by an anterior and a posterior root which unite outside it to form the trunk of the spinal nerve. Many of these nerves branch and

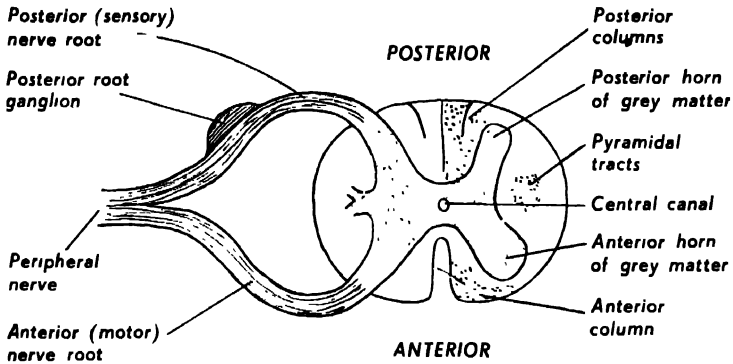


Fig. 17.6 Transverse section of the spinal cord showing the grey matter and the position of the tracts in the white matter.

unite to form plexuses from which nerves are distributed to various parts of the body. The cervical plexus is made up by the first to fourth cervical nerves. the brachial by the fifth cervical to first

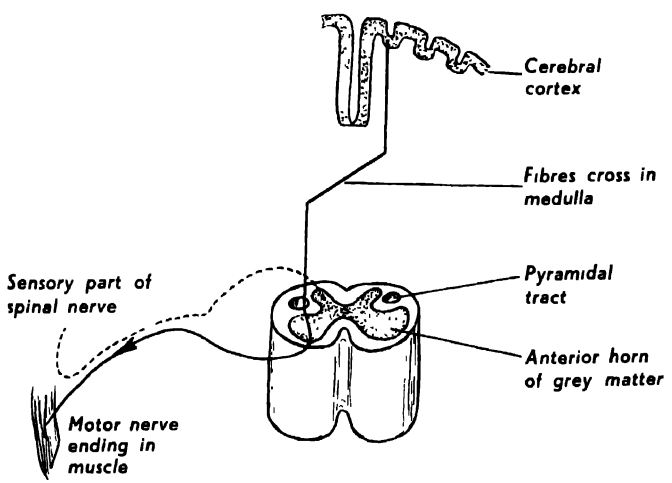


Fig. 17.7 The motor path.

thoracic, the lumbar by the first to fourth lumbar and the sacral plexus by the fourth lumbar to fifth sacral nerves. The nerve to the diaphragm, the phrenic, comes from the cervical plexus, the nerves

to the arm come from the brachial and those to the legs come from the lumbar and sacral plexuses.

THE MOTOR PATH (see Fig. 17.7)

The motor impulses originate in the cells of the precentral gyrus of the cerebral cortex and travel down the upper and lower motor neurons.

The *upper motor neuron* starts, therefore, in the grey matter of the brain and continues down as the axon of the brain-cell in the white matter. In the medulla oblongata the axon crosses to the opposite side and then travels by the pyramidal tract in the lateral column of

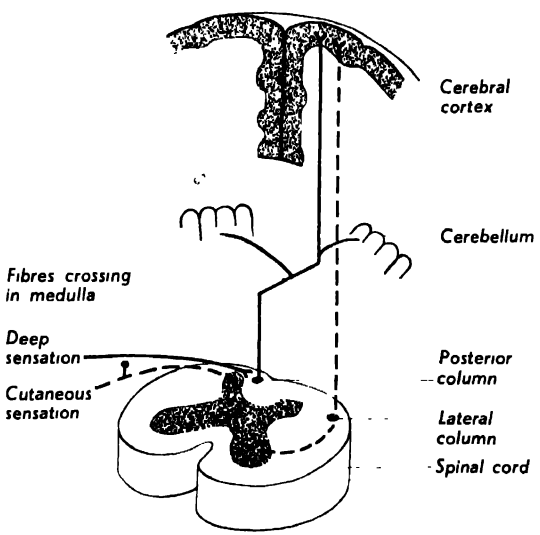


Fig. 17.8 The sensory path.

the white matter of the spinal cord. It terminates in an anterior horn cell of spinal grey matter.

The *lower motor neuron* begins in an anterior horn cell and continues as the axon of this cell passing through the anterior nerve root to the main trunk of the spinal nerve and so reaches its destination, for example, a muscle.

THE SENSORY PATH *(see Fig. 17.8)*

The sensory impulses which travel in the cord are divided into those of superficial sensation such as pain, temperature sense and touch and those of deep sensation such as those from muscles and joints. They travel in fibres which enter the spinal cord by the posterior root and pass to the posterior horn of grey matter. From here the fibres run upwards in bundles or tracts in the white matter of the spinal cord crossing to the opposite side in the cord or lower part of the medulla to end in the postcentral gyrus of the cerebral cortex of the opposite side of the body from which they originated. Some fibres carrying sensations which do not enter consciousness end in the cerebellum.

REFLEX ACTION

A reflex is a motor response, such as the activity of a gland when it secretes or a movement produced by a muscular contraction resulting from a sensory stimulus. A reflex is usually involuntary and for its production it requires:

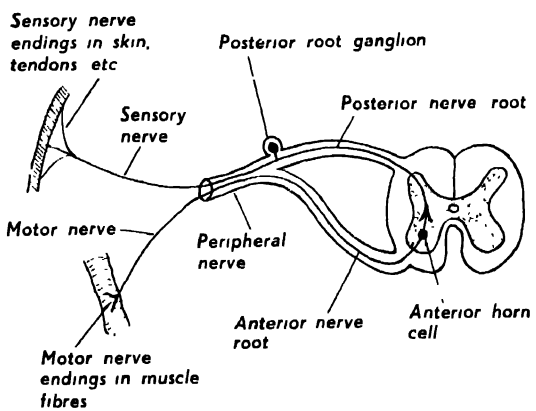


Fig. 17.9 Diagram illustrating reflex action.

(1) A receptor (sensory) organ such as the nerve-endings in the skin, etc., to receive the stimulus.

(2) A sensory or afferent fibre to transmit the impulse to the spinal cord.

(3) Connector fibres between the anterior and posterior horns of the grey matter of the spinal cord.

(4) A motor neuron running from the nerve-cells of the anterior

horn of the spinal grey matter to the organ in which the activity is going to occur.

Examples of reflex activity include coughing and sneezing as a result of inhalation of particles of matter into the nose and larynx, the knee jerk, and the contraction of the pupil when the eye is exposed to light.

THE MENINGES

The brain and spinal cord are surrounded by membranes whose main function is protective. These are the dura mater, the arachnoid mater and the pia mater.

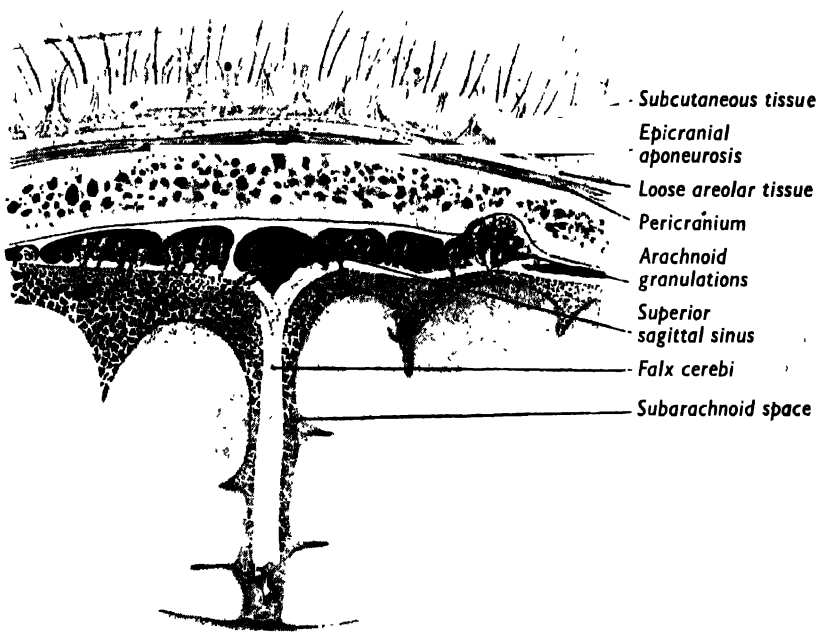


Fig. 17.10 Diagram of coronal section through the scalp and skull. The arachnoid granulations are seen projecting into the superior sagittal sinus.

The *dura mater* is a tough fibrous membrane composed of two layers. It lines the skull and dips between the two cerebral hemispheres forming the *falx* and separates them from the cerebellum by

the *tentorium*. The two layers are fused except at the sites of the venous sinuses of the brain (p. 136) which lie between them.

The *arachnoid mater* lines the dura mater and sends small projections into the venous sinuses known as the *arachnoid villi* and *arachnoid granulations* through which the cerebrospinal fluid is returned to the blood stream.

The *pia mater* is a very thin membrane which closely invests the surface of the brain, dipping into the sulci and carrying blood vessels to the cortex. Between the pia and the arachnoid mater is the *subarachnoid space* which is filled with cerebrospinal fluid, it surrounds the brain and spinal cord and extends down as far as the second sacral vertebra.

THE CEREBROSPINAL FLUID

This fluid fills the ventricles and subarachnoid space. It is secreted by the choroid plexuses of the ventricles and leaves the ventricular system by passing into the subarachnoid space through the foramina in the roof of the fourth ventricle. It is absorbed from the subarachnoid space into the blood stream through the arachnoid villi and arachnoid granulations which project into the venous sinuses.

The cerebrospinal fluid is similar to lymph, being a clear colourless slightly alkaline fluid containing protein, glucose and salts. It acts as a protective cushion for the brain and spinal cord, it carries nourishment from the blood to the brain and spinal cord and it removes excreta from them.

THE AUTONOMIC NERVOUS SYSTEM

The autonomic nervous system consists of a series of nerves and ganglia which control the involuntary functions of the body. Whereas the central nervous system is principally concerned with the reception of sensory impulses and the stimulation of voluntary muscle, the autonomic nervous system is principally concerned with the innervation of the secretory glands and the involuntary (unstriped) muscle of the body such as that of the heart,* blood vessels and uterus. This system is not under control of the will but it is intimately connected with the thalamus, the part of the brain associated with the emotions.

* Heart muscle is involuntary but, strictly, it should not be classified as unstriped (Chapter 3).

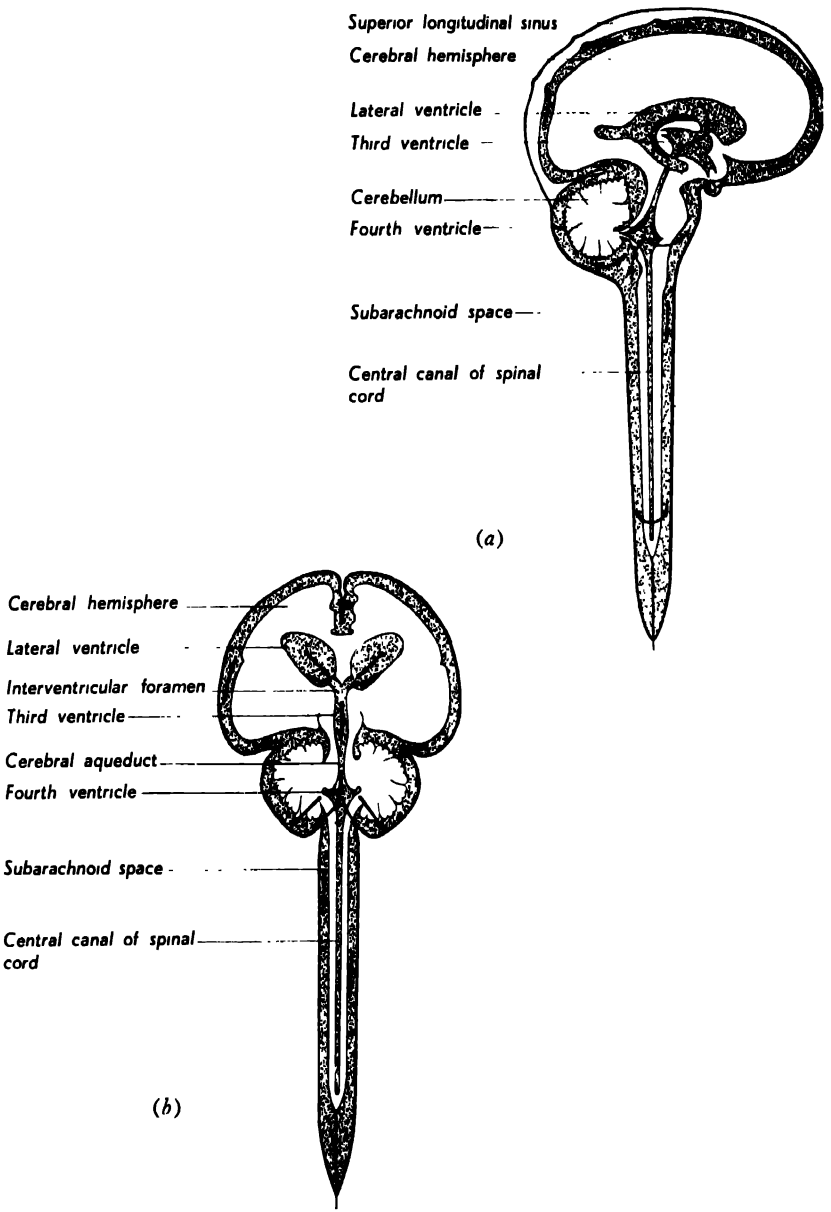


Fig. 17.11 The circulation of the cerebrospinal fluid (diagrammatic) (*a*) seen from the side, (*b*) seen from the back.

The nerves and ganglia of this system are derived from the central nervous system and are grouped as follows:

(1) The sympathetic nervous system.
(2) The parasympathetic nervous system.

The *sympathetic nervous system* consists of a series of ganglia in the neck, chest (the cardiac plexus) and abdomen (the solar plexus, etc.) which are connected to the thoracic and upper lumbar portions of the spinal cord. From the ganglia the sympathetic nerve-fibres pass to all parts of the body. The function of this part of the autonomic system is similar in effect to the injection of adrenaline, and indeed the suprarenal medulla which secretes adrenaline develops from the same embryological tissue. The sympathetic and parasympathetic nervous systems are antagonistic to each other and stimulation of the sympathetic results in accceleration of the heart, constriction of the cutaneous and alimentary blood vessels, contraction of the sphincters, relaxation of the bronchi and dilatation of the pupils of the eyes.

The *parasympathetic nervous system* comprises the *cranial part* and the *sacral part*. The former consists of fibres which are distributed to the pupils of the eyes, the blood vessels and secretory glands of the head and neck; and the vagus nerve which supplies many organs in the neck, chest and abdomen. The sacral part of the parasympathetic system is derived from the sacral segments of the spinal cord and is distributed through its ganglia to the lower parts of the alimentary canal, the genital organs, etc.

As the sympathetic and parasympathetic nervous systems are opposed in their functions it follows that stimulation of the latter results in slowing of the heart, contraction of the pupils, dilatation of blood vessels and relaxation of sphincters.

Radiographic Appearances of the Central Nervous System

Among the radiographic methods which may be used for studies of the central nervous system are the instillation of air into the ventricular system (ventriculography and encephalography), the injection of an opaque medium into the carotid and vertebral arteries (cerebral arteriography) and the injection of another opaque medium into the spinal subarachnoid space (myelography).

Encephalography and ventriculography will demonstrate the ventricles of the brain if the patient's head is suitably positioned, as

the air will tend to collect in the uppermost parts of the cavities. In the lateral projection the lateral ventricle of the uppermost side will be shown and the anterior horns of both lateral ventricles will be filled when the patient is supine.

Injections of air for encephalography and of the opaque medium for myelography may be made by *lumbar puncture*. A suitable needle is inserted between the laminae of the third and fourth lumbar vertebrae and cerebrospinal fluid escapes when the subarachnoid space has been reached. There is no fear of damage to the cord because, of course, this terminates between the first and second lumbar vertebrae.



Fig. 17.12 Radiograph of the skull, lateral projection, showing the lateral ventricle of one side outlined by air.

In myelography the opaque medium is made to ascend and descend the spinal subarachnoid space by tilting the table in the appropriate direction. The medium will normally descend as far as the second sacral vertebra because the subarachnoid space extends down to this level.

Pathological Considerations

Damage to the motor tracts of the brain is often caused by

haemorrhage or thrombosis resulting from arterial disease. Paralysis of one-half of the body, called *hemiplegia*, may follow. Pressure on the spinal cord by fracture-dislocations of the spine, prolapsed intervertebral discs or spinal tumours may cause paralysis of the lower limbs, a condition known as *paraplegia*. If all four limbs are paralysed the patient is *quadriplegic*. Infantile paralysis (anterior poliomyelitis) often destroys some of the anterior horn cells of the spinal cord and produces what is known as a flaccid paralysis (in contradistinction to a spastic paralysis which follows damage to the upper motor neuron).

Tumours of the brain may cause a rise in intracranial pressure and this may result in thinning or destruction of the posterior clinoid processes and dorsum sellae, enlargement of the pituitary fossa and, in children, separation of the cranial sutures.

Tumours of the auditory canal called *acoustic neuromas* may occur and they may produce expansion of the auditory canal which can be demonstrated radiologically.

The circulation of the cerebrospinal fluid may be impeded by a block in the cerebral aqueduct (e.g. a tumour) or inflammatory disease of the meninges causing adhesions in the subarachnoid space or blocking the foramina in the roof of the fourth ventricle. Under these circumstances the continued formation of the fluid results in distension of the ventricles and pressure atrophy of the brain. This condition is known as *hydrocephalus* (water on the brain). It is now possible to relieve the condition by surgical procedures.

18

The Special Senses

Sensations may be divided into those arising within the body such as thirst, hunger, muscle sense, etc., and those, called the special senses, arising from external stimuli such as sight, hearing, taste, smell and touch.

SIGHT

The organ of sight is the eye and it has various accessory structures which include the eyebrows, the eyelids, the conjunctiva, the

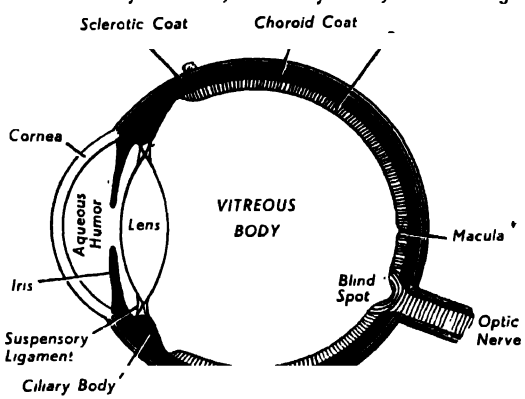


Fig. 18.1 Section through the eyeball.

lacrymal apparatus (all protective in function), and the muscles which are responsible for the synchronized movements of the eyes.

The *eyeball* is a mechanism for modifying light waves so that they will stimulate the nerve endings in the retina. It consists of three coats which enclose a number of transparent structures. The outer coat or *sclera* forms the white of the eye and is a tough fibrous layer which gives the eye its shape and is transparent anteriorly where it is called the *cornea.* The middle coat or *choroid* is vascular and pigmented and is continuous with the *iris.* The innermost coat, the

retina, is continuous with the optic nerve and is composed of nerve endings which are sensitive only to light.

The eyeball is divided into an *anterior* and a *posterior chamber*. The anterior chamber contains the transparent *aqueous humour* and is separated from the posterior chamber by the *lens*. The incoming light rays are focused by the lens, the curvature of which can be varied by contraction of the muscles of the ciliary body (accommodation). The posterior chamber is occupied by the transparent *vitreous humour*. The amount of light entering the eye is controlled by

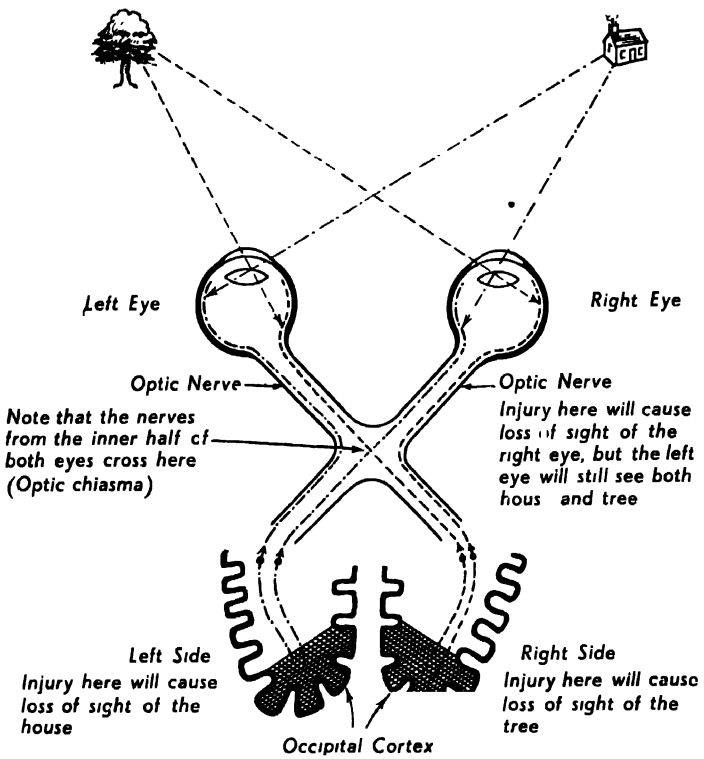


Fig. 18.2 Diagram of the visual paths.

the iris, a pigmented structure composed principally of smooth muscle, which dilates in poor light and contracts in bright light.

The retina consists of nerve-cells and is developmentally part of the brain. The nerve-fibres are greatly modified and are called *rods* and *cones*. The cones are used for vision in good lighting conditions whereas the rods are used for 'night vision', they do not function in

bright light as they require the presence of a pigment called *visual purple* which is bleached by exposure to light. Exclusion of light from the eyes for 15-20 minutes or the wearing of red goggles results in the recovery of visual purple; this is called *dark adaptation.*

That part of the retina to which the optic nerve is attached is devoid of rods and cones and is called the *blind spot.* Lateral to this and in the centre of the retina directly behind the pupil is the most sensitive part; it is called the *macula* and is rich in cones but has no rods, so it is not used in 'night vision'.

The nerve impulses resulting from the stimulation of the retina by light are transmitted by the optic nerves to the optic chiasma where fibres from the inner half of each retina cross to the opposite side so that when they are distributed to the occipital cortex impulses from the right half of each retina will be distributed to the right side of the brain and those from the left side will go to the left side of the brain.

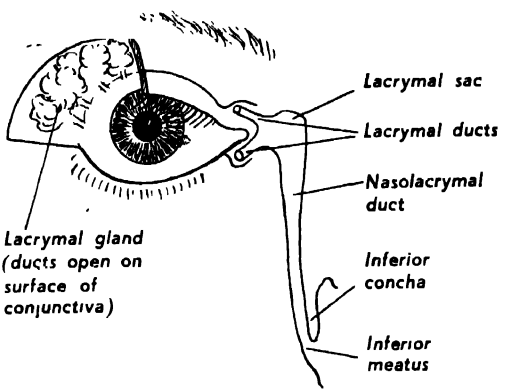


Fig. 18.3 The lacrymal apparatus.

The *conjunctiva* is a very thin mucous membrane which lines the eyelids and covers the cornea.

The *lacrymal apparatus* consists, on each side, of the *lacrymal gland,* a pair of *lacrymal ducts* and, leading from the inner part of each orbit to the inferior meatus of each side of the nose, the *nasolacrymal ducts.* The glands lie above the outer parts of the eyes and the *tears* which they produce pass via the upper and lower lacrymal ducts to the nasolacrymal ducts and thus reach the nose.

HEARING

The ear consists of the external, middle and internal ears and in

addition to being the organ of hearing it is concerned with the maintenance of the body's equilibrium.

The *external ear* consists of the *pinna* or auricle and the *external auditory meatus*, a bony and cartilaginous canal which leads to the middle ear but is separated from it by the *drum* or *tympanic membrane*. The bony part of the meatus lies between the petrous temporal bone above and the tympanic part of the temporal bone below.

The *middle ear* is a narrow cavity in the petrous part of the temporal bone and contains three tiny bones or ossicles called the *malleus* (hammer), the *incus* (anvil) and the *stapes* (stirrup). The lateral wall is formed by the tympanic membrane and the medial wall is bony but has two membrane-covered apertures which separate it from the vestibule above and the cochlea below, called

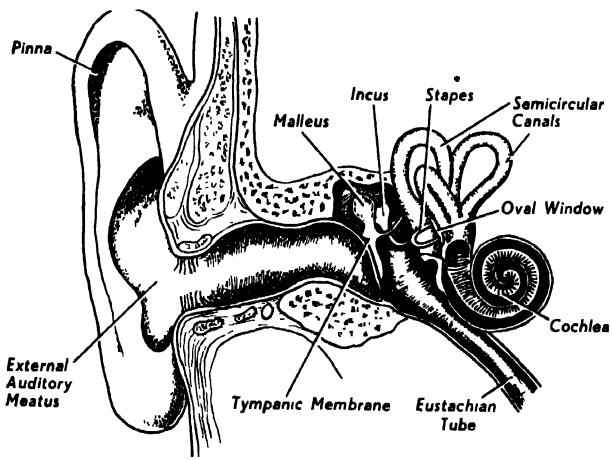


Fig. 18.4 The structure of the ear.

the *fenestra ovalis* and the *fenestra rotunda* respectively. The mastoid air cells and mastoid antrum communicate with the middle ear through its posterior wall.

The *auditory* (*Eustachian* or *pharyngotympanic*) *tube* which connects the middle ear to the pharynx (p. 145) opens into the anterior wall of the middle ear cavity and enables the pressure in this cavity to be adjusted to that of the atmosphere because, although the walls of the tube are normally in contact with each other, the movements of swallowing and yawning separate them. Sudden ascent or descent, as in an elevator in a high building, alter the pressure which the atmosphere is exerting on the ear-drum and swallowing is often required to adjust the pressure in the middle ear and relieve the

discomfort felt in the drum when the pressures on either side of it are different.

The *internal ear* or *labyrinth* is the part of the ear concerned with balance as well as hearing and consists of a number of communicating membranous structures, namely, the vestibule, the cochlea and the semicircular canals, containing fluid called *endolymph*. They lie in the *bony labyrinth* which is formed by similarly shaped cavities

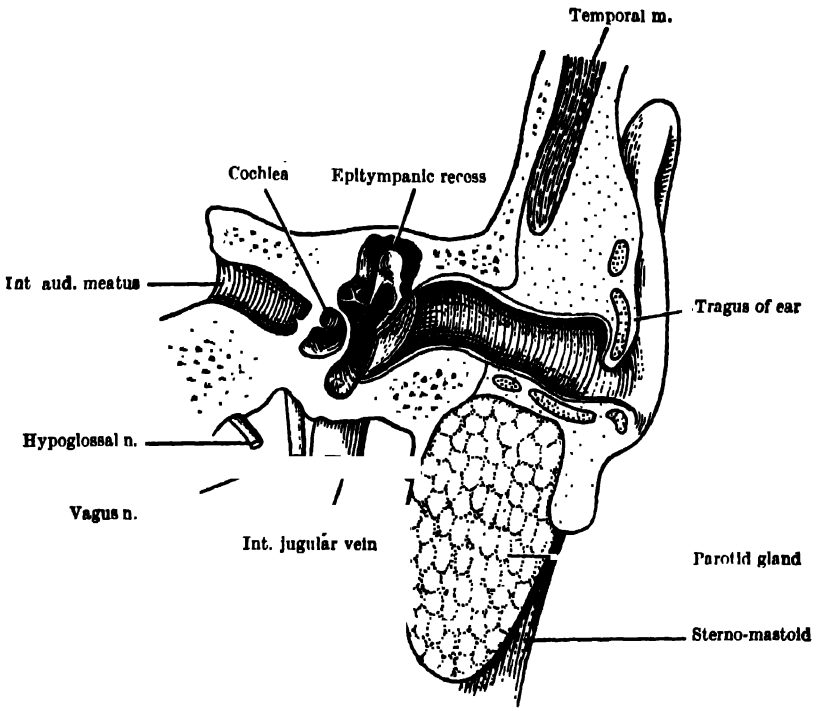


Fig. 18.5 Coronal section through the external and internal auditory meatus (diagrammatic).

in the petrous parts of the temporal bone; fluid called *perilymph* separates the bony from the membranous parts.

The *cochlea*, the organ of hearing, is a coiled structure projecting forwards from the vestibule and in shape is somewhat like a snail. It contains layers of specialized cells called the *organ of Corti* which come into intimate contact with the auditory part of the eighth (auditory) nerve (p. 246) where the sound vibrations are converted into nerve impulses.

The Mechanism of Hearing

The cavity of the middle ear is crossed by the ossicles, the malleus being connected to the tympanic membrane, the stapes to the membrane covering the fenestra ovalis and the incus intervening between them. Vibrations of the tympanic membrane produced by sound waves which have entered the external auditory meatus are transmitted by movement of the ossicles across the middle ear to the membrane covering the fenestra ovalis, from which they are transferred to the perilymph and endolymph. The cochlea is stimulated by the vibratory movement of the endolymph and the organ of Corti converts the stimuli into impulses which the auditory nerve conducts to the brain.

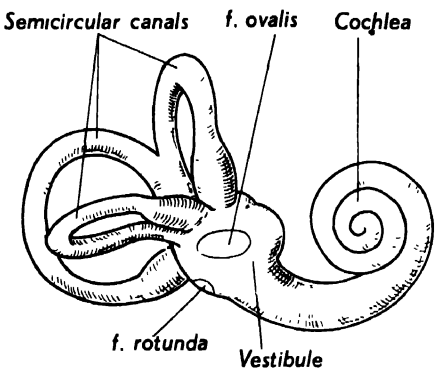


Fig. 18.6 The bony labyrinth.

The *semicircular canals* are the organs which provide one of the means by which the position of the body in space can be appreciated. It will be recalled that sensory impulses from muscles and joints provide another mechanism for the orientation of the body. The canals are called the superior, the posterior and the lateral, and they are so placed that they are at right angles to each other. They communicate individually with the vestibule and contain endolymph and a special sensory mechanism which comes into intimate contact with the vestibular part of the auditory nerve. The sensory mechanism is stimulated by movement of the endolymph resulting from alteration in the position of the head and this information is carried

to the brain where the auditory nerve has connections with both the cerebrum and the cerebellum.

Taste and Smell

These are closely related sensations dependent upon chemical stimulation. The special end-organs of taste are called taste buds and these are found in groups on the dorsum, sides and tip of the tongue and in the mucous membrane of the palate and pharynx.

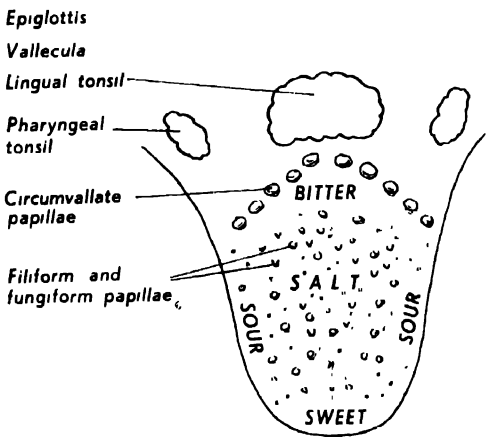


Fig. 18.7 The parts of the tongue in which the various sensations of taste are appreciated.

They are sensitive to the four primary taste sensations, sweet, bitter, sour and salt, and sensitivity to each is localized to a particular part of the tongue. The aroma or flavour of food is appreciated by the sense of smell and this close association of taste and smell is common knowledge, much of the sense of taste being lost in the presence of a cold in the nose.

The sense of smell is stimulated by inhaled gases or particles of soluble matter and is readily fatigued. The end-organs of the olfactory nerve lie in the mucous membrane of the upper part of the nasal cavity.

Cutaneous Sensations

The skin possesses four different types of end-organ which are sensitive to heat, cold, pain and touch respectively. These are

scattered over the surface of the body but are more concentrated in some areas than others. The acuteness of these sensations depends on the concentration of the particular nerve endings, for instance, the finger tips are rich in touch end-organs and they are particularly sensitive in this respect.

19

urface Anatomy and Surface Markings

THE HEAD AND NECK

The *nasion* is the depression at the root of the nose and it lies just below the *glabella* which is the slight elevation on the frontal bone between the two eyebrows. Two ridges, the *superciliary arches*, run laterally from the glabella, and the frontal air sinuses lie deep to

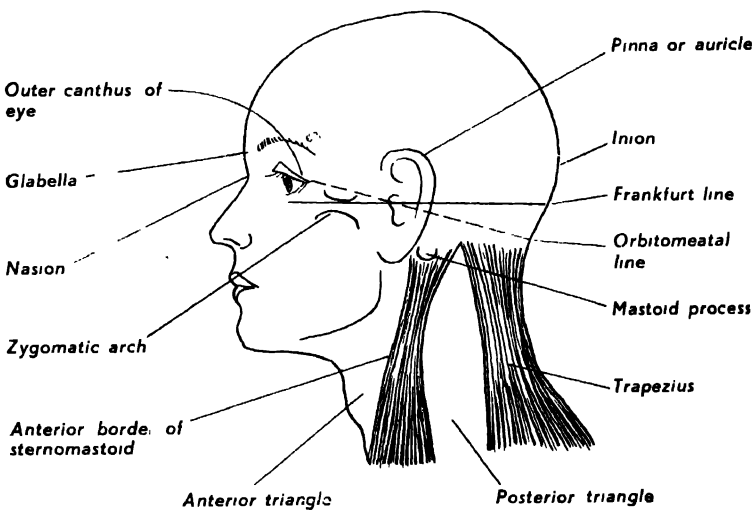


Fig. 19.1 Lateral view of head showing various landmarks and the anterior and posterior triangles of the neck.

them. The *inion* or external occipital protuberance is a localized prominence on the occiput at the junction of the back of the head with the back of the neck. Immediately behind the ear is the *mastoid process* and in front of the external auditory meatus the *zygomatic arch* runs forwards towards the orbit.

The *inner* and *outer canthi* (sing. canthus) are the junctions of the

eyelids. The outer canthus can be joined to the external auditory meatus by the *orbitomeatal line*. Another line, the *Frankfurt line*, is also used in radiographic positioning; it joins the lower orbital margin to the upper margin of the external auditory meatus. The *interpupillary line* is the line passing through the centres of the pupils of the eyes.

The *sella turcica* (pituitary fossa) lies 1 inch (2.5 centimetres) in front of and the same distance above the external auditory meatus.

The medial border of the *sternomastoid muscle* can be felt running from the mastoid process to the manubrium of the sternum and this serves as a surface marking for the position of the common, internal and external carotid arteries. This muscle also divides the neck into

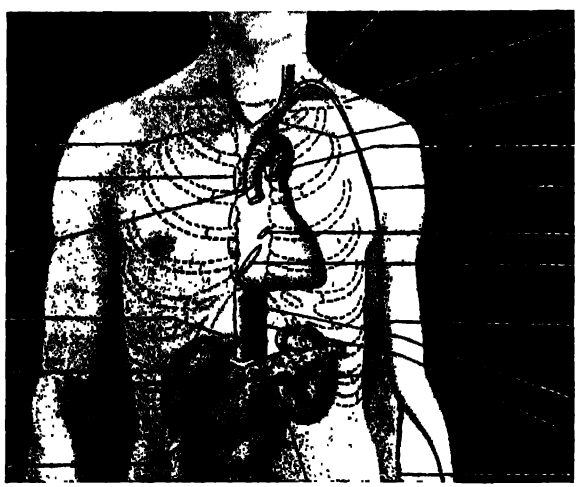


Fig. 19.2 The heart and great vessels. Duodenum, pancreas, kidneys, etc.

the anterior and posterior triangles. In the former are the larynx, the trachea and the thyroid gland.

At the junction of the neck and back the prominent spinous process which can be felt easily is usually that of the seventh cervical vertebra and it is often called the *vertebra prominens*.

THE LARYNX

This region is easily palpated and, if the finger is run down the front of the neck from the chin, the upper border of the thyroid cartilage is felt immediately below the hyoid bone at the level of the middle of the third cervical vertebra. The anterior arch of the

cricoid cartilage is palpable immediately below the thyroid cartilage at the level of the lower border of the sixth cervical vertebra.

THE THYROID GLAND

This lies on the anterior and lateral aspect of the upper six rings of the trachea. The isthmus lying about ½ inch (1 centimetre) below the cricoid cartilage and the lower poles of the lateral lobes reaching about 1 inch (2.5 centimetres) below this.

THE THORAX

The *sternum* is subcutaneous and can be palpated throughout its length. Its upper margin is on a level with the lower part of the body of the second thoracic vertebra. The second costal cartilage can be felt at the level of the *sternal angle* which forms an obvious prominence anteriorly and corresponds to the interspace between the fourth and fifth thoracic vertebrae posteriorly. In the female the *breast* occupies approximately from the second to the sixth ribs and extends from the lateral margin of the sternum to the anterior axillary fold. The nipple lies at about the level of the fourth intercostal space.

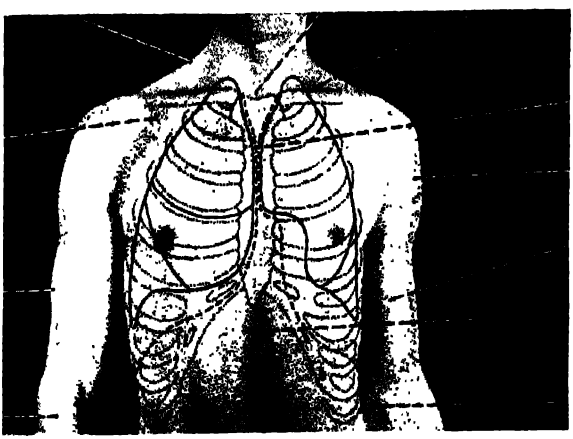


Fig. 19.3 The lines of pleural reflection.

The *heart* lies behind the sternum and extends in the recumbent position from the sternal angle above to about 1½ inches (4 centimetres) beyond the xiphisternal joint below. The right border lies about 1½ inches (4 centimetres) to the right of the midline (i.e.about ½ inch (1 centimetre) to the right of the sternum). The apex is

situated about $3\frac{1}{2}$ inches (9 centimetres) to the left of the midline, behind the fifth intercostal space and the left border extends from this point to the left side of the sternal angle. In the erect position the heart moves down nearly an inch in relation to the sternum. The *arch of the aorta* lies behind the lower half of the manubrium of the sternum.

The *apex of the lung* and *upper limit of the pleura* reach to about $1\frac{3}{4}$ inches (4.5 centimetres) above the middle of the clavicle but inferiorly the lung does not reach the lower limit of the pleura owing to the presence of the costodiaphragmatic recess. The *lower limit of the pleura* is represented approximately by a line with a slight upward inclination drawn round each side of the body at the level of the twelfth thoracic spinous process. This line should pass through the eighth rib in the nipple line, the tenth in the midaxillary line, the eleventh in the midscapular line and the twelfth at the lateral margin of the sacrospinalis muscle. The *lower border of the lung* is approximately two intercostal spaces above that of the pleura.

The *bifurcation of the trachea*, that is the division of the trachea into the two main bronchi, is at the level of the sternal angle.

THE ABDOMEN

The regions of the abdomen and the lines which divide them have already been described in Chapter 13.

Bodily Types

It is obvious that human beings vary between the extremes of those with long narrow trunks and those with short broad ones; the disposition of the abdominal organs depends partly on the body type of the individual. We may thus recognize the slender trunk type (also called asthenic or hyposthenic) and the broad trunk type (or hypersthenic).

The *slender trunk type* has a narrow subcostal angle, a long lumbar spine, abdominal organs which are low lying and a heart that tends to be long and narrow.

The *broad trunk type* has a wide subcostal angle and a short lumbar region. The abdominal organs tend to be high and the heart is more transversely placed than in the slender type.

Between these extremes is the individual of *average build* (or orthosthenic).

Many *factors influence the position of the viscera* in the individual subject and amongst these are:

(1) Posture.
(2) Respiratory movement.
(3) Muscle tone of the abdominal wall and of the internal organs.
(4) The degree of fullness of hollow viscera.

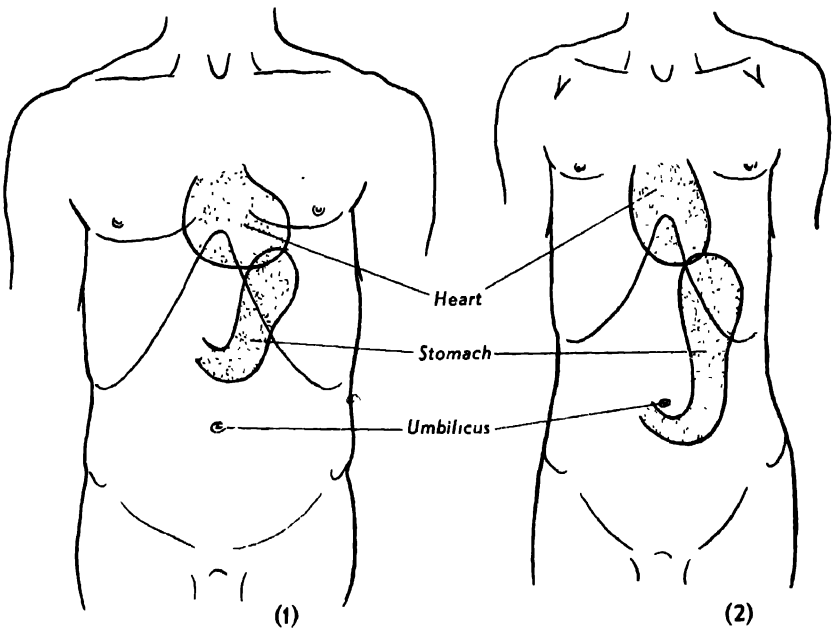


Fig. 19.4 Diagram illustrating (1) the broad trunk type of individual (hypersthenic) and (2) the slender trunk type of individual (hyposthenic).

Posture. When an individual moves from recumbency to the upright position many abdominal viscera descend about 2 inches (5 centimetres).

Respiratory movement. If an individual inspires deeply using his diaphragm many abdominal viscera will descend 2 or 3 inches (5–7 centimetres).

The degree of fullness of hollow viscera. The most obvious example of this factor influencing the position of internal organs is the displacement which occurs in the presence of a pregnant uterus.

The *transpyloric plane* lies approximately midway between the umbilicus and the joint between the xiphoid and the body of the sternum and it forms the boundary between the upper two rows of

the regions of the abdomen. This plane indicates the position of many important organs and in the expiratory phase with the subject recumbent the following structures lie at this level:

(1) The pylorus.
(2) The duodenojejunal flexure.
(3) The upper border of the pancreas.
(4) The hila of the kidneys; the right is an inch or so lower than the left and the centre of each hilum is about 2 inches from the midlines.
(5) The tip of the ninth costal cartilage.
(6) The fundus of the gall-bladder.
(7) The upper part of the body of the first lumbar vertebra
(8) The lower end of the spinal cord.

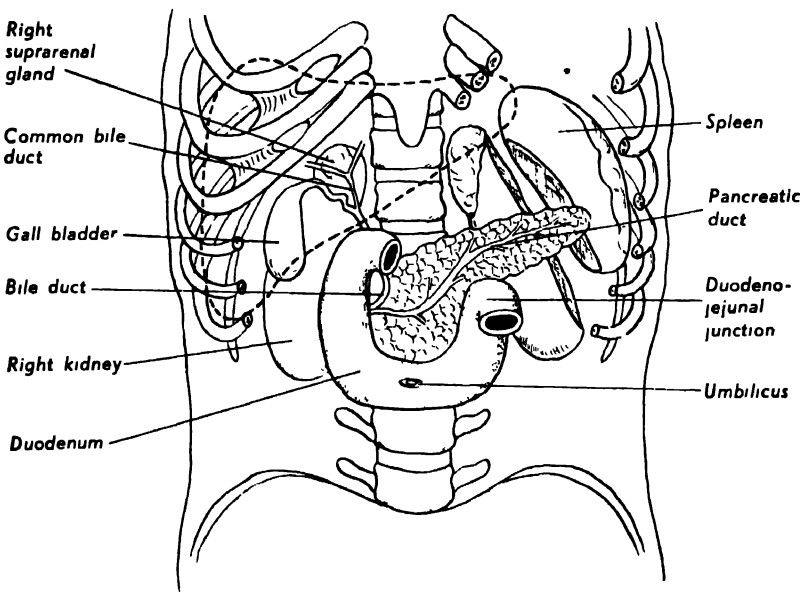


Fig. 19.5 Diagram showing the organs in the upper part of the abdomen.

The *umbilicus* lies at the level of the interspace between the third and fourth lumbar vertebrae and about $\frac{1}{2}$ inch below it the *aorta* divides into the *common iliac arteries.*

The Liver

The *upper surface of the liver* may be represented on the surface of a subject lying supine by drawing a line horizontally at the level of the

xiphisternal joint from a point 3 inches (7.5 centimetres) to the left of the midline to the right axilla; the *lower border* may be drawn by connecting the left extremity of this line to the lowest part of the right costal margin laterally and the *right border* will coincide with the chest wall laterally.

The Spleen

The long axis of the spleen corresponds with the posterior part of the left tenth rib reaching from the mid-axillary line anteriorly to 1½ inches (4 centimetres) from the midline posteriorly.

The Pancreas

The pancreas runs across the posterior abdominal wall from its head which lies in the curve of the duodenum, on the right of the first and second lumbar vertebrae, to its tail which lies in the left hypochondrium where it ends near the hilum of the spleen. The pancreas lies obliquely its tail being at a higher level than its head but the upper border of its body is approximately on the level of the transpyloric plane. The lower border of the body is about 1½ inches (3 4 centimetres) below the upper and the two borders meet at the termination of the tail of the gland.

The Kidneys

In a subject lying supine the hila of the kidneys, at the end of expiration, are approximately at the level of the transpyloric plane which crosses the middle of the costal margin; the right kidney is usually about 1 inch (2.5 centimetres) below the left and both hila are about 2 inches (5.0 centimetres) from the midline. Bearing in mind that the kidneys are about 4½ inches (12 centimetres) long and 2 inches (5.0 centimetres) wide and that the hila are approximately midway between the upper and lower ends their positions can thus be mapped out on the anterior abdominal wall. In relation to the spine the kidneys extend from the twelfth thoracic to the third lumbar vertebra and the hila are opposite the first lumbar vertebra.

The Ureters

The ureter of each side runs from the hilum of the kidney (on the transpyloric plane 2 inches (5 centimetres) from the midline) downwards and medially to the level of the pubic tubercle.

The Urinary Bladder

The empty bladder in the adult lies behind the pubic bones and

the symphysis but as it fills it rises into the hypogastric region. In childhood the bladder is principally an abdominal organ because the pelvic cavity is relatively much less spacious than in the adult.

The Uterus

The non-pregnant uterus lies behind and above the bladder, that is, low in the hypogastrium.

THE UPPER LIMB

The *clavicle* is subcutaneous throughout its course and below its outer end is the *coracoid process*. Lateral to this is the *head of the humerus* and above this the *acromion* can be felt. The *axilla* is the angle between the arm and the chest and the *cubital fossa* is in front of the elbow. On the back of the elbow the *medial* and *lateral epicondyles* and the *olecranon* process form easily palpable prominences. The line of the *elbow joint* is $\frac{3}{4}$ inch (2 centimetres) below that which joins the two epicondyles. The *radial* and *ulnar styloid processes* can be palpated on either side of the lower end of the forearm and the position of the wrist joint corresponds to a line, convex upwards, joining these processes. The *scaphoid* is immediately distal to the radial styloid process.

THE LOWER LIMB

The *hip joint* lies $\frac{1}{2}$ inch (1 centimetre) below the middle third of the *inguinal ligament* and the latter corresponds in position to the fold of the groin. The *greater trochanter* of the femur is the most prominent bony structure palpable on the lateral side of the thigh. At the back of the knee is the *popliteal fossa* and anteriorly about $1\frac{1}{2}$ inches (4 centimetres) below the lower border of the *patella* when the knee is extended is the *tibial tuberosity*. About $\frac{1}{2}$ inch (1 centimetre) below the lower border of the patella in the same position is the *line of the knee joint*. The medial surface of the tibia is subcutaneous and at its lower end the *medial malleolus* forms a prominence. The lower end of the fibula, the *lateral malleolus*, lies on a plane posterior to the medial malleolus and reaches to a lower level. In front of the base of the lateral malleolus the lower end of the tibia can be felt and the *ankle joint* will lie immediately below this.

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